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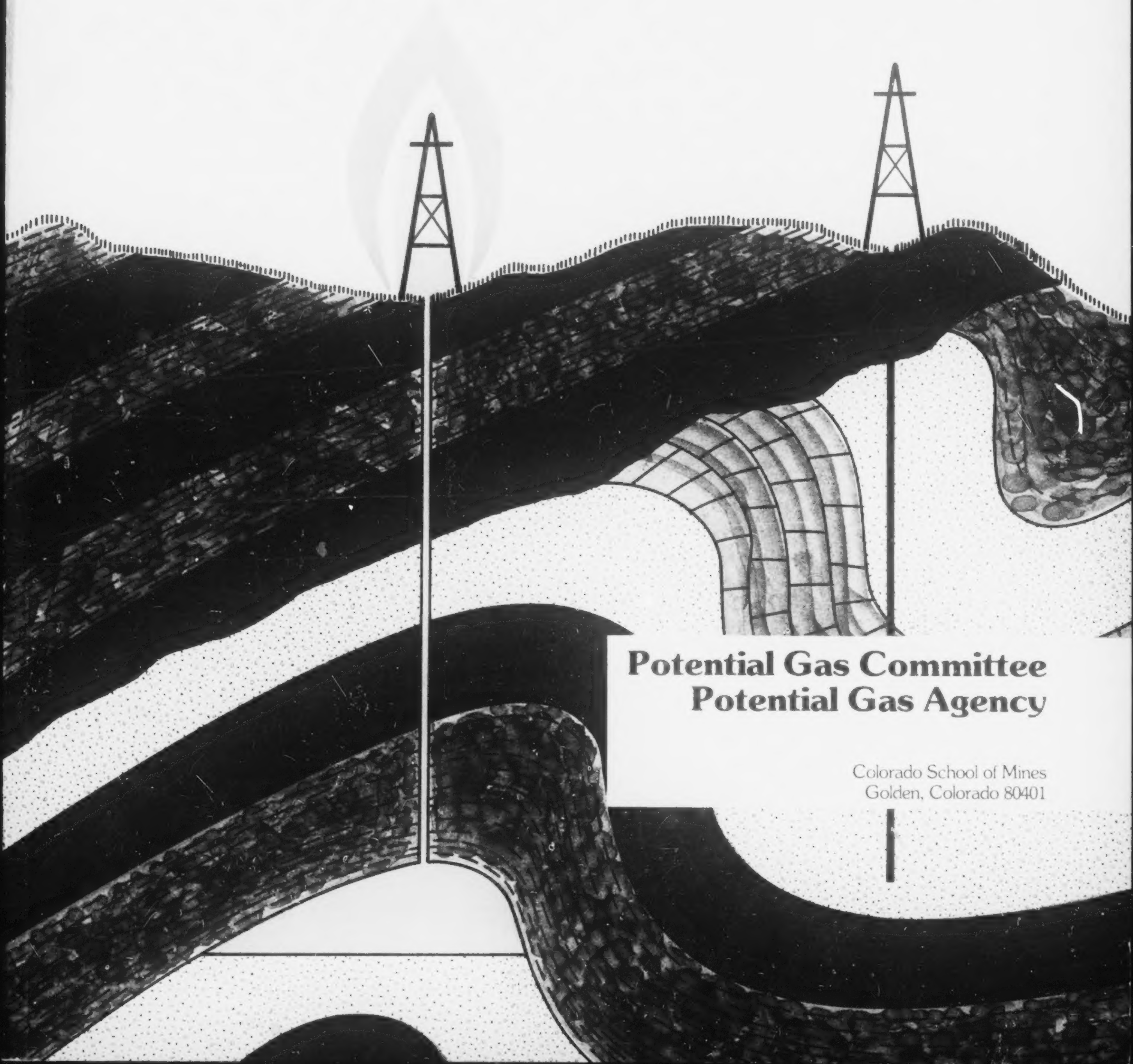
POTENTIAL SUPPLY OF NATURAL GAS IN THE UNITED STATES

(December 31, 1986)



Potential Gas Committee
Potential Gas Agency

Colorado School of Mines
Golden, Colorado 80401

The Potential Gas Committee comprises volunteer members from the natural gas industry, government agencies, and academic institutions who are concerned with natural gas resources.

The Committee functions independently but with the guidance and assistance of the Potential Gas Agency of the Colorado School of Mines. The Potential Gas Agency is supported by the American Gas Association.

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POTENTIAL SUPPLY OF NATURAL GAS IN THE UNITED STATES

(December 31, 1986)

Report of the Potential Gas Committee

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Potential Gas Agency
Colorado School of Mines

April 1987

"When you can measure what you
are speaking about, and express
it in numbers, you know
something about it."

Sir William Thomson,
Lord Kelvin, 1824-1907

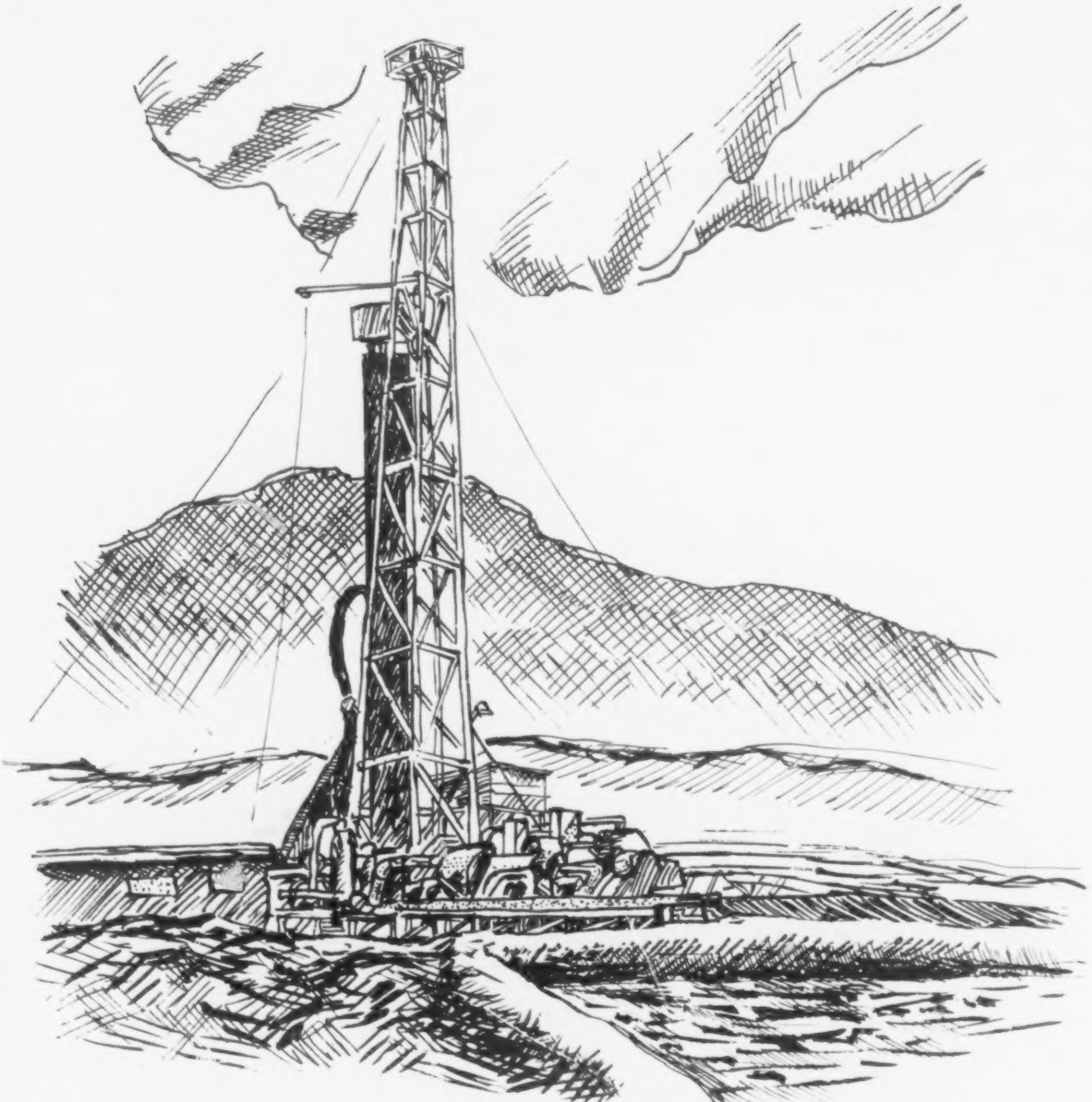
PREFACE

The objective of the Potential Gas Committee is to provide estimates, based upon expert knowledge, of the potential supply of natural gas which, in conjunction with estimates of proved reserves of natural gas, make possible an appraisal of long-range gas supply.

For many years, estimates of future supply of natural gas have been developed by numerous individuals and organizations. Since these estimates of future supply have varied widely and often have had entirely different objectives and meanings, they have served to confuse rather than to clarify the long-range outlook for natural gas supply. With the view toward achieving a more unified industry-sponsored effort, many leaders of the natural gas industry, as well as various financial and governmental agencies, sought a longer-range, ongoing study of the requirements and supply of natural gas in the United States. As a result of this concern, the work of the Potential Gas Committee was initiated in 1960. The Committee, in early years known as the Future Gas Supply Committee, has functioned since that time and has prepared regular reports presenting estimates of the recoverable natural gas which is believed to exist in addition to proved reserves. Since 1967 the work of the Committee has been guided and assisted by the Potential Gas Agency of the Colorado School of Mines.

Discussions of the geology and the natural gas potential are presented for each of the geographic areas included in 87 geologic provinces of the lower 48 states and Alaska. Fifty-four of these geologic provinces are in onshore areas and 33 are offshore. For each of the onshore provinces, separate estimates are given for (1) resources estimated to occur at drilling depths of less than 15,000 feet and (2) those estimated to occur at drilling depths between 15,000 and 30,000 feet. Offshore provinces are separated into those that occur beneath water depths of less than 200 meters (continental shelf) and those that occur beneath water depths of 200 to 1,000 meters (upper continental slope).

Resource estimates for each geologic province are given in terms of maximum, most likely, and minimum estimates. The Potential Gas Committee believes that this manner of reporting gives users an understanding of the uncertainty involved in the resource estimate for any one province. Resource estimates in this report are expressed in terms of billion cubic feet (Bcf) of estimated natural gas resource potential.



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REPORT OF THE POTENTIAL GAS COMMITTEE

Summary

The Potential Gas Committee comprises volunteer members from all segments of the oil and gas industry, government agencies and academic institutions who are concerned with natural gas resources. This Committee has prepared and published biennial estimates of the potential supply of natural gas since 1964, with the exception of 1974. Members of the Committee, their experience and affiliations, are listed in the last section of this report. The Committee functions independently but with the guidance and assistance of the Potential Gas Agency of the Colorado School of Mines. The Potential Gas Agency is supported by the American Gas Association.

The Potential Gas Committee's most likely estimate of the potential supply of natural gas in the United States, as of December 31, 1986, is as follows (table 1):

The sum of these estimates represents a most likely total resource potential of 738,556 billion cubic feet (Bcf).

The foregoing estimates represent the conventional potential natural gas resources expected to be recovered by future drilling under conditions of:

1. adequate economic incentives in terms of price/cost relationships, and
2. current or foreseeable technology.

Estimates of the PGC are "base-line" estimates in that they attempt to provide a reasonable appraisal of the total natural gas resource potential of the United States and are not limited by assumptions of the time of development of the natural gas resource, the life span of the natural gas industry, or the specific price to be paid for the produced gas. There is no consideration of whether or not this resource *will* be developed; rather, the estimates are of the resource that *could* be developed if the need and economic incentive exist. Estimates also assume no governmental or regulatory restraints upon the development and production of the resource.

Table 1. Estimated potential natural gas resources (billion cubic feet)

	Most likely estimates		
	Probable	Possible	Speculative
Lower 48 States			
--Onshore	128,183	200,046	156,169
--Offshore	25,462	69,148	40,768
Total Lower 48 States	153,645	269,194	196,937
Alaska			
--Onshore	6,590	16,400	27,690
--Offshore	2,400	12,700	53,000
Total Alaska	8,990	29,100	80,690
Total United States	162,635	298,294	277,627

The Potential Gas Committee's estimates do not include, and are distinct and separate from, the volume of proved recoverable natural gas reserves contained in the nation's discovered fields. The relationship between proved reserves and the several categories of potential natural gas resources is illustrated in figures 2 and 3, and described in detail in the section on Categories of Natural Gas Resources.

The Potential Gas Committee's previously published estimates, as of December 31, 1984, were as follows (in trillion cubic feet): Probable 185, Possible 293, and Speculative 306. More detail is included in table 10 and in the reports of the various areas.

Comparison of the totals of the most likely estimates of potential resources for year-end 1986 with those presented at the end of 1984 indicates decreases in the categories of Probable and Speculative resources, but a slight increase in the total estimate of Possible resources. These changes reflect the current status of a dynamic system in which former potential resources pass into proved reserves and production through discovery and development of new pools and fields (figure 1). Concurrently, the estimates of remaining potential resources are revised based on knowledge gained through additional exploration and drilling.

A considerable portion of the change in resource estimates between succeeding biennial reports of the Potential Gas Committee is represented by the additions to Proved Reserves which have taken place in the preceding two years. Such reserve additions are estimated to the best of their ability by PGC members based upon available data, and the additions are then removed from the appropriate resource categories. Decreases in estimates of Probable resources occur because of field development and additions to reserves as a result of extensions of the producing area of the pool or field. Additions to estimates of Probable resources are made based upon the undeveloped areas of fields which have been discovered and are under development at the time the resource estimates are prepared. Estimates of Possible resources are decreased based upon new field discoveries and increased when new provinces or formations are demonstrated to be productive of natural gas. Estimates of Speculative resources are reduced based upon new field discoveries and may be increased if new data indicate additional, previously

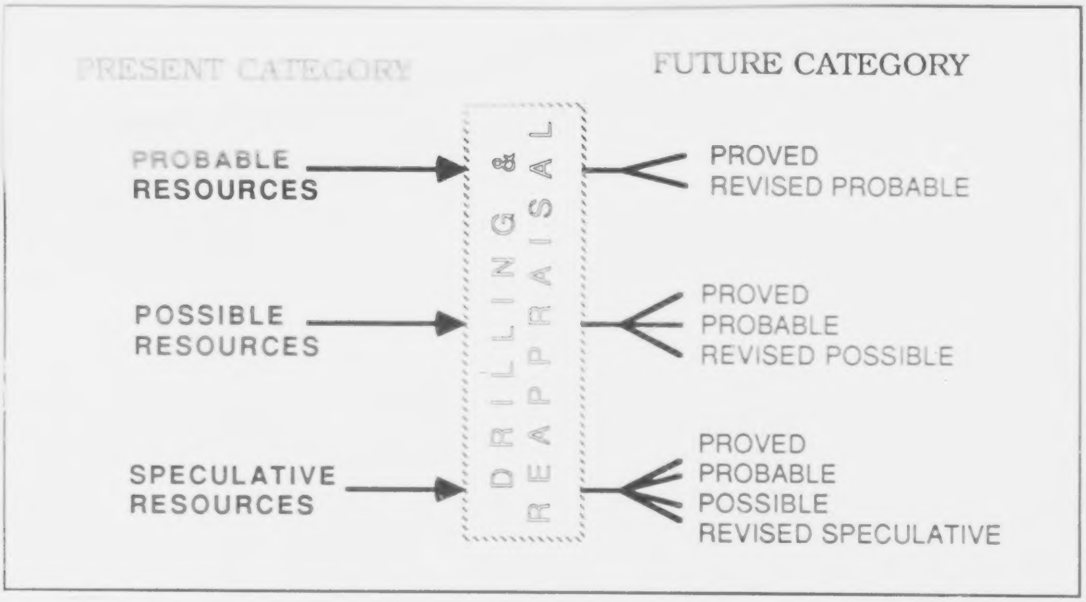

Figure 1. Schematic representation of progression of categories of potential natural gas resources as a result of drilling and reappraisal

unrecognized, potential for natural gas discoveries and production.

In addition to expected changes resulting from potential resources passing into Proved Reserves, the following significant changes in resource estimates have been made:

In the Michigan Basin province (P-200) evaluation of new data has resulted in an increase in the estimate of Possible resources.

In the Gulf Coast Area several changes have been made in resource estimates. Developments in the Eastern Gulf of Mexico, shelf and slope (provinces P-930 and P-931), as well as adjacent onshore regions in the Louisiana-Mississippi-Alabama Salt Basins Province (P-300), related to the Lower Mobile Bay Norphlet play, have resulted in reevaluation of the natural gas potential for this region. Estimates of most likely Probable resources have been increased slightly with a corresponding decrease in some estimates of Possible and Speculative resources. The study demonstrated that a much larger portion of the shelf (P-940) resources should be classified as Possible rather than Probable, with the total most likely estimate remaining essentially unchanged.

In the Texas Offshore, shelf and slope provinces (P-940 and P-941), have been completely reevaluated in view of the fields discovered to date and additional data available as a result of the newly instituted area-wide leasing programs. The most likely estimate of Probable resources for P-941 was reduced because only three fields are currently under development. However, the estimate of Possible resources was increased based on the new data. The slope province is still in the early stages of exploration, and large portions of the shelf province have been only sparsely drilled.

In the Mid-Continent Area reevaluation of the resource potential has resulted in some increases in estimates for two provinces. Based on additional resources which are being developed by increasing the density of wells drilled, the most likely estimates for all resource categories have been increased for the Arkoma basin (province P-410). Most likely estimates of resources for the deep portion of the Anadarko basin in Province P-420 have been increased based on restudy of available data.

In the Rocky Mountain Area estimates of potential resources are approximately 14% lower for the total of all resource categories than the corresponding total at the end of 1984. The change results primarily from changes in estimates for three provinces. The estimates for the Unita and Piceance basins (province P-540) have been reduced approximately 30% based on a very detailed analysis of future potential based on well performance. The estimates for the Wyoming-Utah-Idaho Thrust Belt (province P-590) have been reduced about 26% based on two facts: (1) recent drilling, plus seismic data, indicate little room for additional major accumulations in the Fossil basin and immediate vicinity; and (2) drilling and seismic data show that the prolific reservoirs which are located in the Mesozoic and upper Paleozoic rocks of the Fossil basin are not present in the hanging wall of the thrust fault north of the Fossil basin--the only remaining objectives are in the Madison Limestone (Mississippian) and older rocks. A detailed study of the Greater Green River basin (province P-530) has resulted in increasing the most likely estimates for all categories of resources in the shallow depths of the basin, as well as the most likely estimate of Possible resources in the deeper potion of the basin, and in decreasing the most likely estimates for deep Probable and Speculative resources.

In Alaska, results of exploratory tests in the Gulf of Alaska and the Bering Sea offshore basins of Norton Sound, St. George and Navarin have been negative. As a result of these disappointments, the most likely estimates of Speculative resources for Alaska have been reduced by 19%.

Introduction

The estimates of the Potential Gas Committee are of natural gas which, in the judgment of Committee members, can be recovered by conventional means given adequate economic incentives in terms of price/cost relationships and utilizing current or foreseeable technology. Since these potential resources have not yet been confirmed by drilling and testing, there can be no rigorous evaluation of the economic viability of the resources. The accumulations, however, are believed to exist in concentrations which are of sufficient size and quality, considering geographic distribution and depth of occurrence, to warrant exploration and development.

The Potential Gas Committee's estimates do not include proved reserves. Annual estimates of proved reserves of natural gas in the United States were prepared, from 1946 through 1979, by the Committee on Natural Gas Reserves of the American Gas Association. Currently that Committee publishes an annual report containing estimates of proved reserves for selected fields.[1] Since 1977, and continuing to the present, annual estimates of proved reserves have been prepared independently by the Energy Information Administration of the US Department of Energy[2]. These estimates are, by definition, limited to those estimated proved recoverable reserves of natural gas which have been established by drilling. Such estimates do not reflect potential resources of natural gas which may be discovered as a result of future exploratory drilling. It is the estimates of potential resources which are the concern of the Potential Gas Committee and which are discussed in this report.

Additionally, the Potential Gas Committee estimates do not include natural gas which may be recovered in the future from unconventional sources. Such unconventional resources are not currently recoverable with existing technology and under current or foreseeable economic conditons. As technology and economic conditons change, the Potential Gas Committee reviews its estimates and revises them as appropriate.

Definition of Natural Gas

Natural gas, as used in this report, is any gas (at standard conditions of temperature and pressure, 14.73 psia and 60° F) of natural origin that is composed primarily of hydrocarbon molecules producible from a borehole. Most natural gas contains some nonhydrocarbon components, such as carbon dioxide, nitrogen, hydrogen sulfide and helium. In estimating potential supply, it is not feasible to separate small volumes of these components from the hydrocarbons; however, in areas where significant volumes of such nonhydrocarbons are believed to occur, only the hydrocarbon components are included in the estimated potential supply.

Categories of Natural Gas Resources

A finite volume of natural gas-in-place exists within the rocks of the shallow portion of the earth's crust. This finite volume of gas-in-place is the total natural gas resource. The amount of this resource that is recoverable is a function of technology and economics. The categories of this resource are shown in figure 2. Today, technology has advanced to the degree that a significant part of the natural gas resource base can be recovered. A major part of this resource, however, is dispersed throughout the earth's crust in such minute accumulations or under such conditions that it cannot be extracted with existing or foreseeable technology. Also, the cost of recovery of such gas would be too high compared to the value of the gas. Even with likely advances in technology, production of some deposits would not be feasible because recovery of such accumulations would require more energy than that provided by the gas produced. The recoverable resource is that part of the natural gas

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[1] American Gas Association, 1986, Natural Gas Reserves of selected Fields in the United States and of Canada prepared by the American Gas Association and the Canadian Petroleum Association as of December 31, 1985.

[2] Energy Information Administration, 1986, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1985 Annual Rejport: U.S. Department of Energy, Energy Information Administration, Washington , D.C., 93 p. [DOE/EIA-0216(85)] and reports for earlier years).

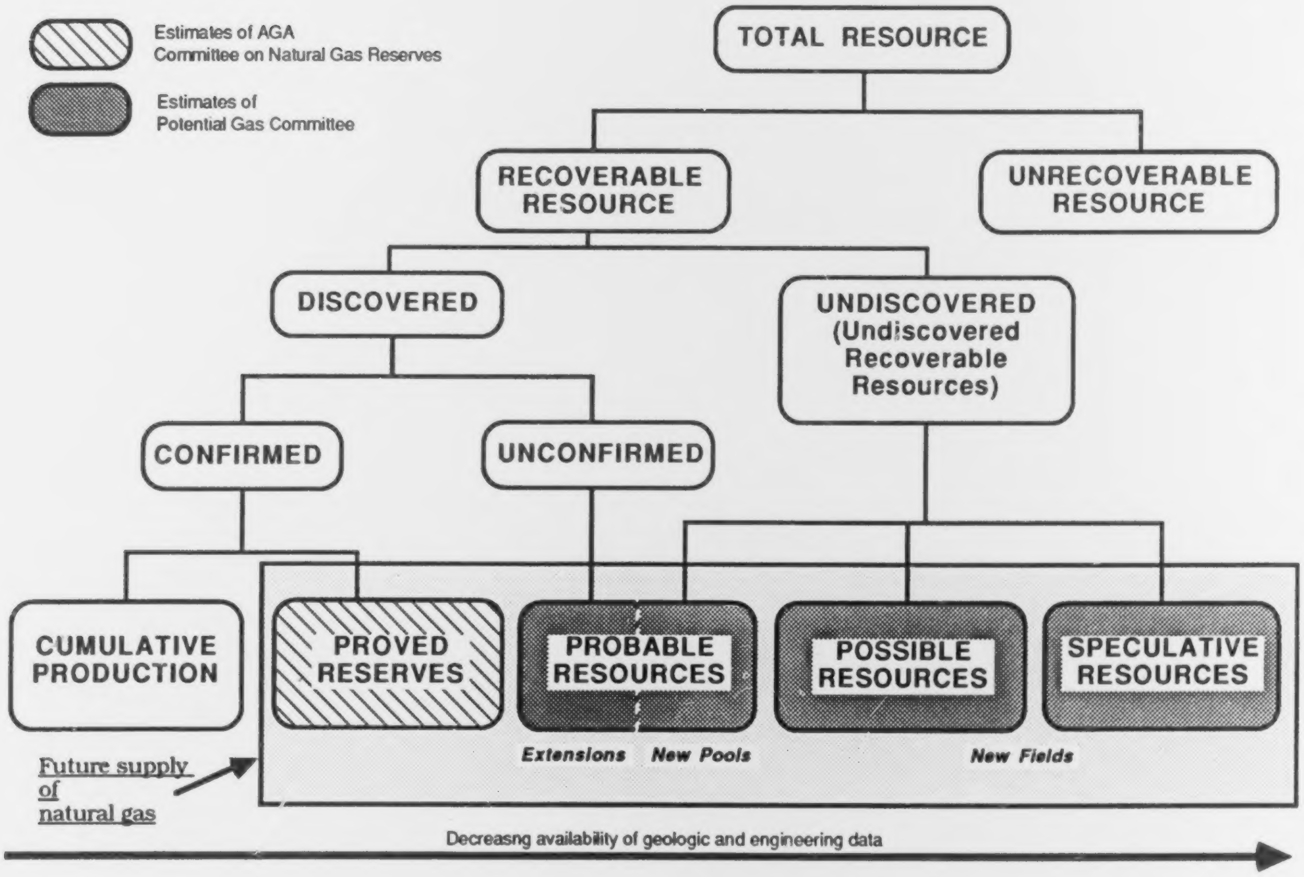
Estimates of AGA
Committee on Natural Gas Reserves
Estimates of
Potential Gas Committee
TOTAL RESOURCE
RECOVERABLE RESOURCE
UNRECOVERABLE RESOURCE
DISCOVERED
UNDISCOVERED (Undiscovered Recoverable Resources)
CONFIRMED
UNCONFIRMED
CUMULATIVE PRODUCTION
PROVED RESERVES
PROBABLE RESOURCES
POSSIBLE RESOURCES
SPECULATIVE RESOURCES
Extensions
New Pools
New Fields
Future supply of natural gas
Decreasng availability of geologic and engineering data

Figure 2. Natural gas resource categories

resource that is susceptible to discovery and production during the life of the industry using current or foreseeable technology and under the condition that the price/cost ratio would be favorable.

The above limitations of size of accumulation and economics are applied as follows. For situations in which a distribution of sizes of individual accumulations is envisioned (particularly in estimation of probable and possible resources, as described below), a minimum size of recoverable accumulation is determined on the basis of the estimator's current judgment of the relationship between the value of the resource and the cost of drilling and production. This relationship is based on extrapolation of the prevailing price/cost ratio at that time for the given geologic province and depth. This often takes the form of an estimate of the minimum recovery per well, which is necessary in order for an operator to determine that it is economically feasible to complete and produce the well in a given geographic area and depth. Such a well may not, in total, be an economically viable venture, but given that the well has already been drilled to the target, the available resource will be produced and will probably recover the costs of completion and production, even if the total costs of exploration and drilling are not recovered. At the other end of the size and economic spectrum, a maximum size of accumulation is estimated on the basis of the estimator's evaluation of the geologic factors controlling the size and effectiveness of traps and the reservoir conditions.

The size and economic limitations are evaluated in a much more general way in situations in which it is not possible to estimate the number and sizes of individual accumulations. This is particularly the case in the estimation of speculative resources (as discussed below). In these situations, analogies are made with provinces or formations in which natural gas production has already been established and which have similar geologic characteristics to the unexplored province or formation. It is hoped that, if these analogies are drawn carefully and accurately, the analogous conditions of size and economics will also apply.

The *Recoverable Resource* is composed of both *discovered* and *undiscovered* natural gas resources. Discovered gas consists of the quantity produced in past years plus that proved by drilling and engineering tests and included in present *Proved Reserves*. Discovered gas also includes the gas remaining in known fields that will be recovered through extension and complete development of known pools and reservoirs. The undiscovered resource consists of the potential gas supply that could become productive with further exploration and development. The undiscovered resource includes both the gas remaining in undiscovered pools and reservoirs within known fields and the gas that may be discovered in new fields and reservoirs within geologic provinces that are presently productive and those that are as yet unproductive.

The subdivision of the Recoverable Resource into categories reflects the variation in the amount of geologic and engineering information on which the estimate is based. These categories are independent of any interpretation of the cost of development and production of the gas. Proceeding from left to right in figure 2, the level of geologic and engineering knowledge decreases.

Cumulative production is the total volume of natural gas which has been withdrawn from producing reservoirs. Some uncertainty involving the amount of production from earlier years exists as a result of incomplete records, but a reasonable estimate has been made based on available information. Estimates of past production presented in this report have been prepared by the Committee on Natural Gas Reserves of the American Gas Association (A.G.A.). Annual production for years up to 1979 was obtained from the reports of the Committee on Natural Gas Reserves.[3] Annual production for years from 1980 to the present was obtained from the reports of the Energy Information Administration (EIA) of the U. S. Department of Energy.[4]

Proved Reserves are the currently estimated quantities of natural gas which analysis of geologic and engineering data demonstrate with reasonable certainty to be recoverable in the future from known oil and gas reservoirs under existing economic and operating conditions. Reservoirs are considered proved that have demonstrated the ability to produce by either actual production or conclusive formation tests. The existence and quantity of gas have been *confirmed* by testing. The PGC does not estimate volumes of proved reserves. Estimates of proved reserves were compiled annually from 1946 through 1979 by the Committee on Natural Gas Reserves of A.G.A.[5] The A.G.A. estimates have been largely supplanted by reports prepared by EIA which began with data for 1977 and have replaced the A.G.A. estimates for 1980 and subsequent years.[6]

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[3] American Petroleum Institute, American Gas Association, Canadian Petroleum Association, 1979, Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1979: American Petroleum Institute and American Gas Association, Washington, D.C., 253 p. (also annual reports for preceding years).

[4] op. cit.

The estimates of the PGC include all of the undiscovered resource plus the portion of the discovered gas resource that is not included in proved reserves (shaded area in figure 2.) Three categories of potential resources are recognized and reported by the PGC: Probable, Possible and Speculative. These three categories are differentiated on the basis of variation in available geologic, geophysical and engineering information. Estimates of both nonassociated and associated or dissolved gas are included in all categories.

Limitations to the estimates have been established by the PGC on the basis of current technological capabilities and an estimate of the expansion of those capabilities in the foreseeable future. No estimate is made for onshore areas of natural gas that might exist at drilling depths in excess of 30,000 feet. Estimates for onshore areas are also made for two depth intervals, 0 to 15,000 feet and 15,000 to 30,000 feet, in recognition of the greater costs and technical requirements for wells drilled below 15,000 feet. No estimate is made for offshore areas of any natural gas that might exist beneath water depths greater than 1,000 meters. Also, separate estimates are made for offshore areas of resources below water depths of 0 to 200 meters and depths of 200 to 1,000 meters, respectively, because of the higher costs associated with drilling platforms, production facilities and pipelines in deeper water.

Probable resources are associated with known fields and are the most assured of potential supplies. A relatively large amount of geologic and engineering information is available to aid in the estimation of the resource existing in this category. Probable resources bridge the boundary between discovered and undiscovered resources. The discovered portion includes the supply from future extensions of *existing pools* in known productive reservoirs [1].* The pools containing this gas have been discovered, but the extent of the pool has not been completely delineated by development drilling. Therefore, the existence and quantity of gas in the undrilled portion of the pool are as yet *unconfirmed*. The undiscovered portion is expected to come from future *new pool* discoveries within existing fields either in reservoirs productive in the field [2], or in shallower or deeper formations known to be productive elsewhere in the same geologic province or subprovince [3].

Possible potential resources are a less assured supply because they are postulated to exist outside of known fields, but they are associated with a productive formation in a productive province. Their occurrence is indicated by a projection of plays or trends of a producing formation into a less well-explored area of the same geologic province or subprovince. The resources are expected to be found from *new field* discoveries, postulated to occur within these trends or plays under both similar [4] and different [5] geologic conditions (i.e., the types of traps and/or structural settings may either be the same or differ in some aspect).

Speculative resources, the most nebulous category, are expected to be found in formations or provinces that have not yet proven to be productive. Geologic analogs are developed in order to ensure reasonable evaluation of these unknown quantities. The resources are anticipated from *new pool* [6] or *new field* [7] discoveries in *formations not previously productive* within a productive geologic province or subprovince and from *new field* discoveries within a geologic *province not previously productive* [8].

To reiterate, the accuracy of the estimates of potential resources of natural gas is dependent upon geologic conditions and upon knowledge of those conditions and the extent to which the given area has been explored and developed. By following the estimation guidelines as closely as possible, consistency and compatibility of the estimates by members of the PGC are maintained. However, the individual estimator may have to use slight modifications of the considerations and procedures

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[5] op. cit.

[6] op. cit.

*Numbers in brackets refer to accumulations shown diagrammatically in figure 3.

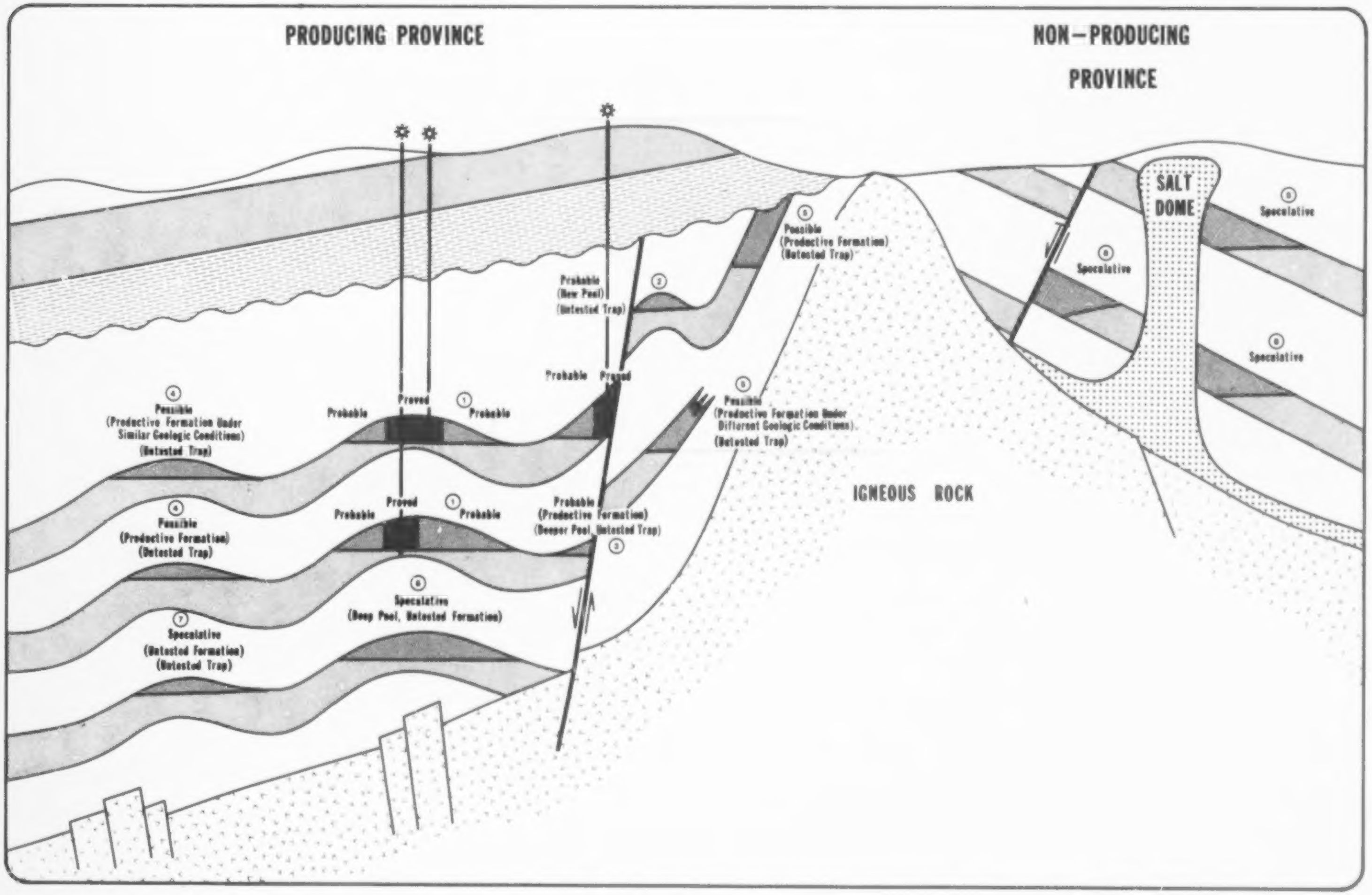
PRODUCING PROVINCE
NON—PRODUCING PROVINCE
Probable (New Pool) (Untested Trap)
②
⑤ Possible (Productive Formation) (Untested Trap)
SALT DOME
⑥ Speculative
⑥ Speculative
⑥ Speculative
Probable
Proved
④ Possible (Productive Formation Under Similar Geologic Conditions) (Untested Trap)
Probable
Proved
① Probable
⑤ Possible (Productive Formation Under Different Geologic Conditions). (Untested Trap)
④ Possible (Productive Formation) (Untested Trap)
Probable
Proved
① Probable
Probable (Productive Formation) (Deeper Pool, Untested Trap)
③
IGNEOUS ROCK
⑥ Speculative (Deep Pool, Untested Formation)
⑦ Speculative (Untested Formation) (Untested Trap)

Figure 3. Schematic representation of categories of potential gas resources

when compiling estimates for each of the three categories because of the particular characteristics applicable to his reporting area.

Estimates of potential resources of natural gas in the United States have also been made by the Resource Appraisal Group (RAG) of the United States Geological Survey (USGS), whose most recently published report is USGS Circular 860[7] and which includes estimates of resources of crude oil and natural gas liquids as well as natural gas. More recently the Minerals Management Service (MMS) of the US Department of the Interior has published estimates of economically recoverable natural gas from the offshore federal lands of the United States.[8] The MMS estimates differ considerably from those of both the USGS RAG and the PGC because of the stringent economic evaluation placed upon the resource evaluation by the MMS.

Although resource terminology of the USGS RAG and the MMS differs from that of the PGC, the USGS and MMS category of Undiscovered Recoverable Resources is essentially equivalent to the combined PGC Possible and Speculative resources (figure 4). The USGS category of Inferred Reserves is essentially equivalent to the PGC category of Probable resources. A further discussion of the resource classification of the US Department of the Interior is set forth in USGS Circular 831.[9]

Explanation for Figure 3--Schematic representation of categories of potential resources

I. Probable resources--Associated with existing fields--most assured,
  1) Discovered--unconfirmed: discovered trap, existing production elsewhere in the trap [1]
  2) Undiscovered: undiscovered trap, productive formation--supply from new pool discoveries within existing field in
    a) reservoir producing within the same field [2]
    b) shallower or deeper formations producing elsewhere within same geologic province or subprovince [3]
II. Possible resources--Associated with productive formations-- less assured,
  1) Similar geologic conditions [4]
  2) Different geologic conditions: e g., stratigraphic vs. structural trap [5]
III. Speculative resources--Most nebulous
  1) From nonproductive formation in productive province
    a) new pool [6]
    b) new field [7]
  2) From nonproductive province [8]

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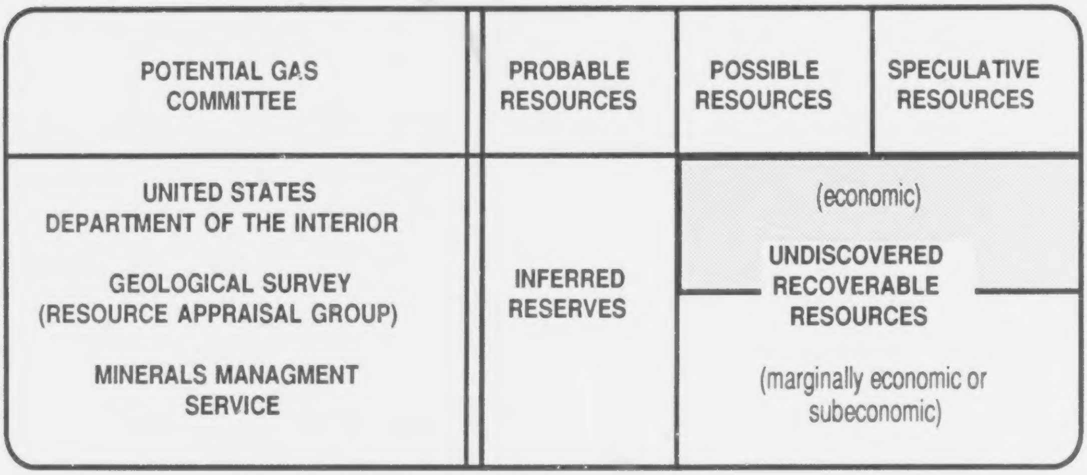
[7] Dolton, G. L. and others, 1981, Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: US Geological Survey Circular 860, 87 p.

[8] Cooke, Larry W., 1985, Estimates of undiscovered economically recoverable oil and gas resources for the Outer Continental Shelf as of July 1984: US Department of the Interior, Minerals Management Service, Offshore Resource Evaluation Division, OCS Report MMS 85-0012, 45 p.

[9] US Bureau of Mines and US Geological Survey, 1980, Principles of a resource/reserve classification for minerals: US Geological Survey Circular 831, 5 p.



POTENTIAL GAS COMMITTEE	PROBABLE RESOURCES	POSSIBLE RESOURCES	SPECULATIVE RESOURCES
UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (RESOURCE APPRAISAL GROUP) MINERALS MANAGMENT SERVICE	INFERRED RESERVES	(economic) UNDISCOVERED RECOVERABLE RESOURCES (marginally economic or subeconomic)	

Figure 4. Comparison of Potential Gas Committee and U.S. Geological Survey/Minerals Management Service natural gas resource classification categories

Estimation of Potential Gas Supply

Geologic provinces

A total of 122 standard geologic provinces has been defined by the PGC (fig. 5; plates 1 and 2). The boundaries of these provinces in the conterminous United States correspond closely to the geologic province boundaries established by the Committee on Statistics of Drilling (CSD) of the American Association of Petroleum Geologists. In some instances, adjacent CSD provinces have been combined by the PGC where these provinces have only limited potential for natural gas resources. Consideration was given to making PGC province boundaries correspond to those used by the Resource Appraisal Group (RAG) of the US Geological Survey. In the conterminous United States, however, the CSD boundaries conform more closely to the geologic boundaries recognized by the working geologists of the PGC and have the advantage of more accessible drilling, discovery and geologic information for the province. Minor changes to province boundaries have also been made where, in the judgment of PGC members, geologic conditions required modification. Provinces for Alaska have been established independently by the PGC on the basis of current understanding of geology and resource potential and do not correspond to provinces established by the CSD or the RAG. Resource estimates are made for each geologic province by members of the PGC.

For purposes of organization, the PGC is subdivided into seven Area Work Committees that correspond to geographic areas of the country. Each area contains a number of geologic provinces, and each committee is responsible for preparation of the resource estimates for the geologic provinces that fall within that area's limits. Membership for the Area Work Committees is recruited from among the geologists and engineers who are actively engaged in exploration and development of natural gas in the various geologic provinces. Since the judgment of the estimator is the most significant single factor in the preparation of resource estimates, every effort is made to recruit the most knowledgeable experts for membership.

Natural gas resources from coal seams

Beginning with this report, a new committee has been formed within the PGC to evaluate resources of natural gas which may be recoverable in the future directly from coal seams throughout the United States. Although understanding of the nature of the coalbed methane resource is incomplete and production history is limited, commercial recovery is taking place and the resource is being recovered. A first report from the Coalbed Methane Committee is contained on pages 121 to 131 of this report. The current lack of data prevents any complete quantitative estimation of the resource at this time. However, the report summarizes the state of our understanding. Quantitative estimates will be included in future reports as knowledge of the resource increases.

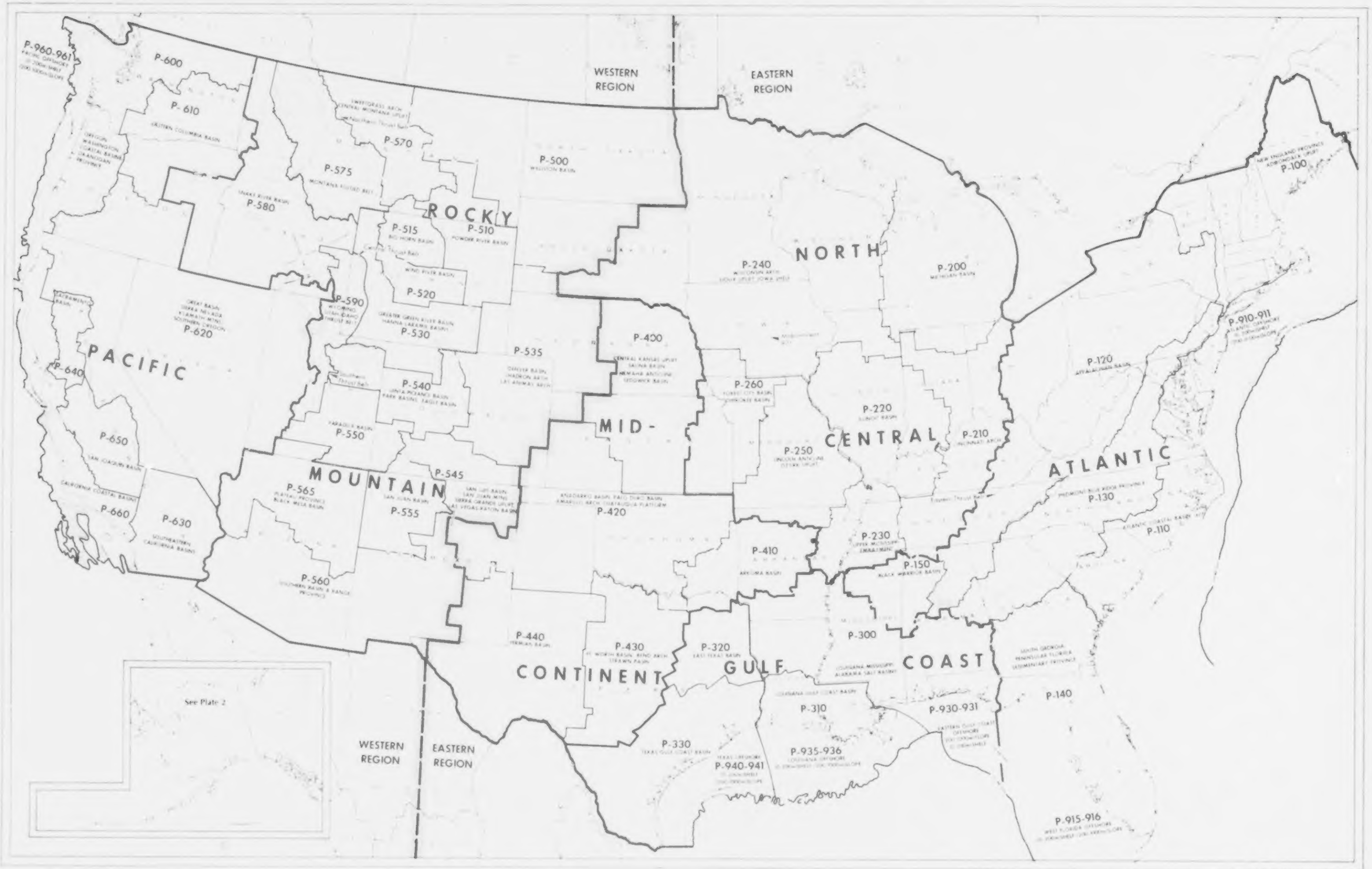

P-960-961
PACIFIC OFFSHORE
P-600
P-610
EASTERN COLUMBIA BASIN
OREGON WASHINGTON COASTAL BASINS & OKANOGAN PROVINCE
WESTERN REGION
EASTERN REGION
SWEETGRASS ARCH CENTRAL MONTANA UPLIFT
Northern Thrust Belt
P-570
P-575
MONTANA FOLDED BELT
P-500
WILLISTON BASIN
SNAKE RIVER BASIN
P-580
ROCKY
P-515
BIG HORN BASIN
P-510
POWDER RIVER BASIN
Central Thrust Belt
WIND RIVER BASIN
P-520
NORTH
P-240
WISCONSIN ARCH SIOUX UPLIFT IOWA UPLIFT
P-200
MICHIGAN BASIN
P-100
NEW ENGLAND PROVINCE ADIRONDACK UPLIFT
SACRAMENTO BASIN
GREAT BASIN SIERRA NEVADA KLAMATH MTNS. SOUTHERN OREGON
P-620
P-590
WYOMING UTAH IDAHO THRUST BELT
GREATER GREEN RIVER BASIN HANNA LARAMIE BASINS
P-530
P-400
CENTRAL KANSAS UPLIFT SALINA BASIN NEMAHA ANTICLINE SEDGWICK BASIN
P-910-911
ATLANTIC OFFSHORE
PACIFIC
P-640
P-535
DENVER BASIN CHADRON ARCH LAS ANIMAS ARCH
P-120
APPALACHIAN BASIN
Southern Thrust Belt
P-540
UINTA PICEANCE BASIN PARK BASINS EAGLE BASIN
P-260
FOREST CITY BASIN CHEROKEE BASIN
P-220
ILLINOIS BASIN
P-650
PARADOX BASIN
P-550
MID-
P-250
LINCOLN ANTICLINE OZARK UPLIFT
CENTRAL
P-210
CINCINNATI ARCH
SAN JOAQUIN BASIN
MOUNTAIN
P-545
ATLANTIC
CALIFORNIA COASTAL BASINS
P-565
PLATEAU PROVINCE BLACK MESA BASIN
SAN JUAN BASIN
P-555
SAN LUIS BASIN SAN JUAN MTNS. SIERRA GRANDE UPLIFT LAS VEGAS-RATON BASIN
ANADARKO BASIN PALO DURO BASIN AMARILLO ARCH CHATAUQUA PLATFORM
P-420
Eastern Thrust Belt
PIEDMONT BLUE RIDGE PROVINCE
P-130
ATLANTIC COASTAL BASIN
P-110
P-660
P-630
SOUTHEASTERN CALIFORNIA BASINS
P-230
UPPER MISSISSIPPI EMBAYMENT
P-410
ARKOMA BASIN
P-150
BLACK WARRIOR BASIN
P-560
SOUTHERN BASIN & RANGE PROVINCE
P-440
PERMIAN BASIN
P-430
FT. WORTH BASIN, BEND ARCH STRAWN BASIN
P-320
EAST TEXAS BASIN
GULF
P-300
LOUISIANA MISSISSIPPI ALABAMA SALT BASINS
COAST
SOUTH GEORGIA PENINSULAR FLORIDA SEDIMENTARY PROVINCE
CONTINENT
See Plate 2
LOUISIANA GULF COAST BASIN
P-310
P-930-931
EASTERN GULF COAST OFFSHORE
P-140
WESTERN REGION
EASTERN REGION
P-330
TEXAS GULF COAST BASIN
TEXAS OFFSHORE
P-940-941
P-935-936
LOUISIANA OFFSHORE
P-915-916
WEST FLORIDA OFFSHORE

Figure 5. Potential Gas Committee work areas and geologic provinces

Estimation procedures

This section presents a brief review of the techniques used by the Potential Gas Committee in preparing estimates of the natural gas resources of the United States. More detail concerning the methodology and its application is contained in the Procedures manual of the Committee.[10]

The basic technique for estimation of potential gas resources is to compare the factors that control known occurrences of natural gas with factors present in prospective areas. This technique is applied to each of the categories adopted by the PGC. In each case, what is known about the prospective area is evaluated relative to what is known about natural gas accumulations which have been discovered in other parts of the same geologic province or in similar geologic provinces. Natural gas occurrences are related to conditions favoring their formation and accumulation, such as the existence of source rocks, sufficient maturation of organic material, and the presence of reservoir rocks and traps. Studies of producing areas provide information on the productive capacity of particular formations and the average size of accumulations. In its simplest form, the estimate of the potential supply is derived by (1) estimating the volume of potential gas-bearing reservoir rock, (2) multiplying this volume by a yield factor,[11] and (3) discounting to allow for the probability that the traps and/or the accumulations exist. Modifications of the basic technique are necessary to accommodate the variations in amount of information available for prospective areas.

Each estimator considers three separate situations in preparing estimates:

1. Maximum potential resource–The quantity of natural gas which might exist and be recoverable under the most favorable conditions. The probability that such conditions might prevail is assumed to be approximately 10 percent or less, and, thus, only a 10 percent or less probability exists that at least this much gas resource is present. This assumes the maximum number of potential traps with favorable source bed and reservoir conditions, the maximum reasonable yield factor, and each trap is filled with recoverable accumulation. Such assumptions would lead to a reasonable estimate of the maximum resource quantity.

2. Minimum potential resource–The existence of the minimum number of traps, the most marginal source beds and reservoir conditions, the minimum reasonable yield factor, and the possibility that many of the traps which might exist would not contain recoverable accumulations of natural gas. In this case, it is assumed that there is approximately a 90 percent or greater probability that at least this much natural gas resource is present. Such assumptions would lead to a reasonable estimate of the minimum resource quantity.

3. Most Likely potential resource–The most reasonable estimate both of the existence of traps and accumulations and the most reasonable assessment of the source bed, yield factor, and reservoir conditions. These conditions would lead to the most likely estimate of the resource quantity.

Estimates of the maximum, most likely and minimum resource potential are given individually for each geologic province. Most likely resource estimates for each province are summed to derive a total resource potential for each Area and for the entire nation. It is believed that the Committee's estimates represent a distribution such that the most likely estimates correspond closely to the statistical mean. Under these conditions the most likely estimates are additive, and the estimates for provinces can be combined to provide estimates for larger areas.

By considering each of the three situations outlined above, the estimator can best express both the limiting conditions within the geologic region and also the most likely estimate of the resource potential. Estimates prepared by the individual estimators are reviewed periodically at meetings of Area Work Committees and by the entire PGC at the national level, in order that a reasonable degree of consistency and uniformity is maintained.

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[10] Potential Gas Committee, 1984, Definitions and procedures for estimation of potential gas resources: Gas Resources Studies Number 2, Potential Gas Agency, Colorado School of Mines, Golden, 16 p.

[11] Yield factors represent the amount of gas expected to be produced from a given unit volume of rock. They are calculated using data from known gas accumulations considered to be most similar to the one being evaluated. The yield is the volume of discovered gas (i.e., cumulative production plus proved reserves) divided by the volume of productive rock containing the discovered gas. The yield factor applied to any prospective area is adjusted to accommodate variations which are appropriate to the prospective area.

Limiting Considerations

The estimates presented here are limited to the contiguous United States, Alaska, and adjacent offshore areas. Hawaii, the island territories and their adjacent offshore areas are not included.

PGC Work Areas and geologic provinces for the Lower 48 states are shown in figure 5 and on plate 1. Alaskan provinces are shown on plate 2.

Drilling depth and water depth limitations

No potential supply of natural gas is included which exists at subsurface depths greater than 30,000 feet or, in offshore areas, where water depths are in excess of 1,000 meters (3,281 feet). Separate evaluations are made for the potential supply existing at onshore drilling depths from 0 to 15,000 feet and from 15,000 to 30,000 feet. These subdivisions recognize the greater technological and economic difficulties of recovering resources that exist below drilling depths of 15,000 feet. In offshore areas, estimates are made for the potential existing beneath water depths of 0 to 200 meters (656 feet) and 200 to 1,000 meters (3,281 feet). Estimates for water depths less than 200 meters essentially represent the potential supply that may be recovered from beneath the Continental Shelf, whereas the estimates for water depths of 200 to 1,000 meters essentially represent resources that may be recovered from beneath portions of the Continental Slope.

The extension of PGC estimates in 1978 to include offshore areas beneath water depths up to 1,000 meters (3,281 feet) was a significant increase from the previous depth limit of 1,500 feet used in reports from1968 through 1976. In the opinion of Committee members, there had been sufficient improvement in drilling, production and offshore pipeline technology by 1978 to warrant this extension of limits in keeping with the Committee's concept of including all natural gas resources which could be produced in the future with normal advances in technology. Current research in offshore drilling and production indicates the possibility that production of natural gas resources from beneath water depths greater than 1,000 meters may be feasible in the later years of this century or in the early years of the 21st century. No estimate of the resources which may occur beneath these deep waters is included in this report. The PGC is studying the feasibility of including, in future reports, estimates for resources beneath water depths of 1,000 to 2,500 meters.

Estimates made by the Area Work Committees include resources which exist beneath areas presently withdrawn or proposed for withdrawal from exploration and development because of governmental action. Where considerable potential exists beneath these withdrawn areas, it is appropriate that estimates of this potential be made and presented in the narrative portion of the report submitted by each Area Committee.

Economic, technological and policy considerations

Economic, technological and governmental policy considerations taken into account in the Potential Gas Committee's estimate of potential gas supply are related to (1) past production and proved reserves of natural gas, and (2) all wells which would be drilled in the future under the assumed conditions of adequate economic incentives in terms of price-cost relationships and current or foreseeable technology. Fundamental economic considerations--which include but are not limited to prices, costs, rates of take, recovery factors, abandonment pressures, etc.--are inherent in the definition of proved reserves:

> ". . . recoverable in the future from known oil and gas reservoirs under existing economic and operating conditions."

Some gas that is actually present in known reservoirs is not producible because of unfavorable present or foreseeable price/cost relationships and, therefore, is not included in recoverable reserves. Furthermore, there are other known gas accumulations of such small size that none of the gas can be produced in commercial quantities under ". . . existing economic and operating conditions." Such considerations result in proved reserves being somewhat less than the total volumes of gas existing in known reservoirs. These same limitations are applicable to the estimates of potential resources. If a fundamental change in economics or technology occurs, estimates of potential resources will be changed accordingly.

The attribution technique presented in the Estimation of Potential Gas Supply section describes relationships between ultimately recoverable volumes of gas from known occurrences and prospective gas accumulations, after appropriate adjustment for variations in geological and reservoir conditions. The explicit assumptions of adequate but reasonable prices and normal improvements in technology in the definition of potential resources relate to improvements in exploration and production techniques. Adequate prices, normal technological improvements and reasonable governmental policies are required to bring about the drilling necessary to prove the potential resources. These assumed conditions permit estimates of potential resources to be made by the PGC on the basis of relevant past history and experience concerning recovery factors, as well as the size and type of reservoirs which have been found, developed, and produced, without speculating as to future levels of prices and costs.

National Summary Statistics

The following tables summarize the Potential Gas Committee resource estimates on a national basis. Additionally, data have been derived from the Committee on Natural Gas Reserves of the American Gas Association,[12] and the Energy Information Administration.[13]

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[12] American Gas Association, 1980, Report of the Committee on Natural Gas Reserves, *in* American Petroleum Institute, American Gas Association, and Canadian Petroleum Association, Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1979 (and earlier years): Washington, D.C.

[13] Energy Information Administration, 1986 U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1985 Annual Report: US Department of Energy, Energy Information Administration, Washington, D.C., Publication DOE/EIS-0216(85 [and earlier years]).

Table 2. Potential Gas Committee 1984 estimates by Area
(Most Likely Values--billion cubic feet)

AREA			PROBABLE	POSSIBLE	SPECULATIVE
Atlantic					
	Onshore	0-15,000'	21,950	8,130	23,370
		15-30,000'	**	**	11,060
		TOTAL	21,950	8,130	34,430
	Offshore	0-200 m	**	**	14,790
		200-1,000 m	**	**	660
		TOTAL			15,450
	AREA TOTAL		21,950	8,130	49,880
North Central					
	Onshore	0-15,000'	187	4,113	10,323
		15-30,000'	**	**	*
	AREA TOTAL		187	4,113	10,323
Gulf Coast					
	Onshore	0-15,000'	10,850	15,660	3,570
		15-30,000'	9,500	21,460	13,380
		TOTAL	20,350	37,120	16,950
	Offshore	0-200 m	23,655	40,575	7,500
		200-1,000 m	1,570	19,660	8,990
		TOTAL	25,225	60,235	16,490
	AREA TOTAL		45,575	97,355	33,440
Mid-Continent					
	Onshore	0-15,000'	30,700	39,500	27,900
		15-30,000'	16,900	51,300	34,200
	AREA TOTAL		47,600	90,800	62,100
Rocky Mountain					
	Onshore	0-15,000'	27,547	29,352	17,762
		15-30,000'	9,004	23,931	7,704
	AREA TOTAL		36,551	53,283	25,466
Pacific					
	Onshore	0-15,000'	1,345	5,450	6,000
		15-30,000'	200	1,150	900
		TOTAL	1,545	6,600	6,900
	Offshore	0-200 m	65	4,735	3,661
		200-1,000 m	172	4,178	5,167
		TOTAL	237	8,913	8,828
	AREA TOTAL		1,782	15,513	15,728
TOTAL LOWER 48 STATES			153,645	269,194	196,937
Alaska					
	Onshore	0-15,000'	6,590	16,400	27,690
		15-30,000'	**	**	*
		TOTAL	6,590	16,400	27,690
	Offshore	0-200 m	2,400	12,700	50,360
		200-1,000 m	**	**	2,640
		TOTAL	2,400	12,700	53,000
	AREA TOTAL		8,990	29,100	80,690
TOTAL UNITED STATES			162,635	298,294	277,627

*Negligible quantity of natural gas estimated.
**Production has not been established; no Probable or Possible resource exists.

Table 3. Potential Gas Committee 1986 estimates--total United States
(Most Likely Values--billion cubic feet)

	PROBABLE	POSSIBLE	SPECULATIVE
ONSHORE (drilling depth)			
Lower 48 states			
less than 15,000 feet	92,579	102,205	88,925
15,000 to 30,000 feet	35,604	97,841	67,244
Alaska			
less than 15,000 feet	6,590	16,400	27,690
15,000 to 30,000 feet	**	**	**
TOTAL ONSHORE	134,773	216,446	183,859
OFFSHORE (water depth)			
Lower 48 states			
less than 200 meters	23,720	45,310	25,951
200 to 1,000 meters	1,742	23,838	14,817
Alaska			
less than 200 meters	2,400	12,700	50,360
200 to 1,000 meters	**	**	2,640
TOTAL OFFSHORE	27,862	81,848	93,768
TOTAL LOWER 48 STATES	153,645	269,194	196,937
TOTAL ALASKA	8,990	29,100	80,690
TOTAL UNITED STATES	162,635	298,294	277,627

**Production has not been established; no Probable or Possible resource exists.

Table 4. Estimated potential supply of natural gas, December 31, 1986
Onshore, 0-15,000'
(Most Likely Values--billion cubic feet)

AREA	PROBABLE	POSSIBLE	SPECULATIVE
Atlantic	21,950	8,130	23,370
North Central	187	4,113	10,323
Gulf Coast	10,850	15,660	3,570
Mid-Continent	30,700	39,500	27,900
Rocky Mountain	27,547	29,352	17,762
Pacific	1,345	5,450	6,000
TOTAL LOWER 48 STATES	92,579	102,205	88,925
Alaska	6,590	16,400	27,690
TOTAL UNITED STATES	99,169	118,605	116,615

Table 5. Estimated potential supply of natural gas, December 31, 1986
Onshore, 15,000-30,000'
(Most Likely Values--billion cubic feet)

AREA	PROBABLE	POSSIBLE	SPECULATIVE
Atlantic	*	*	11,060
North Central	**	**	*
Gulf Coast	9,500	21,460	13,380
Mid-Continent	16,900	51,300	34,200
Rocky Mountain	9,004	23,931	7,704
Pacific	200	1,150	900
TOTAL LOWER 48 STATES	35,604	97,841	67,244
Alaska	**	**	*
TOTAL UNITED STATES	35,604	97,841	67,244

*Negligible quantity of resource estimated.
**Production has not been established; no Probable or Possible resource exists.

Table 6. Estimated potential supply of natural gas, December 31, 1986
Offshore, 0-200 meters water depth
(Most Likely Values--billion cubic feet)

AREA	PROBABLE	POSSIBLE	SPECULATIVE
Atlantic	**	**	14,790
North Central	--	--	--
Gulf Coast	23,655	40,575	7,500
Mid-Continent	--	--	--
Rocky Mountain	--	--	--
Pacific	65	4,735	3,661
TOTAL LOWER 48 STATES	23,720	45,310	25,951
Alaska	2,400	12,700	50,360
TOTAL UNITED STATES	26,120	58,010	76,311

**Production has not been established; no Probable or Possible resource exists.

Table 7. Estimated potential supply of natural gas, December 31, 1986
Offshore, 200-1,000 meters water depth
(Most Likely Values--billion cubic feet)

AREA	PROBABLE	POSSIBLE	SPECULATIVE
Atlantic	**	**	660
North Central	--	--	--
Gulf Coast	1,570	19,660	8,990
Mid-Continent	--	--	--
Rocky Mountain	--	--	--
Pacific	172	4,178	5,167
TOTAL LOWER 48 STATES	1,742	23,838	14,817
Alaska	**	**	2,640
TOTAL UNITED STATES	1,742	23,838	17,457

**Production has not been established; no Probable or Possible resource exists.

Table 8. Comparison of estimates of ultimately recoverable volumes of natural gas in the United States (trillion cubic feet)

Total United States

Year	Cumulative Production (1)	Proved Reserves (2)	Potential Resources (3)	Ultimately Recoverable Resource
1968	345	287	1227	1859
1970	387	291	1178	1856
1972	432	266	1146	1844
1974	477	237	1146	1860
1976	515	216	948	1679
1978	553	200	1019	1772
1980	596	199	913	1708
1982	632	202	876	1710
1984	665	196	784	1645
1986	697	193	739	1629

Lower 48 states

Year	Cumulative Production (1)	Proved Reserves (2)	Potential Resources (3)	Ultimately Recoverable Resource
1966	300	286	690	1276
1968	345	282	795	1422
1970	388	260	851	1499
1972	432	235	780	1447
1974	476	205	780	1461
1976	514	184	748	1446
1978	532	177	830	1539
1980	571	163	768	1502
1982	613	169	742	1524
1984	662	163	647	1472
1986	693	160	620	1473

(1) Cumulative production figures derived from A.G.A. Committee on Natural Gas Reserves, plus annual production reports from US Department of Energy, Energy Information Administration.

(2) Proved reserves derived from reports of the A.G.A. Committee on Natural Gas Reserves for years through 1979. Proved reserves for years from 1980 on are derived from reports of US Department of Energy, Energy Information Administration. Proved reserves shown for 1986 are an estimate only.

(3) Potential resources from estimates of Potential Gas Committee.

Figure 6. Biennial estimates of cumulative production, proved reserves and potential resources of natural gas in the total United States

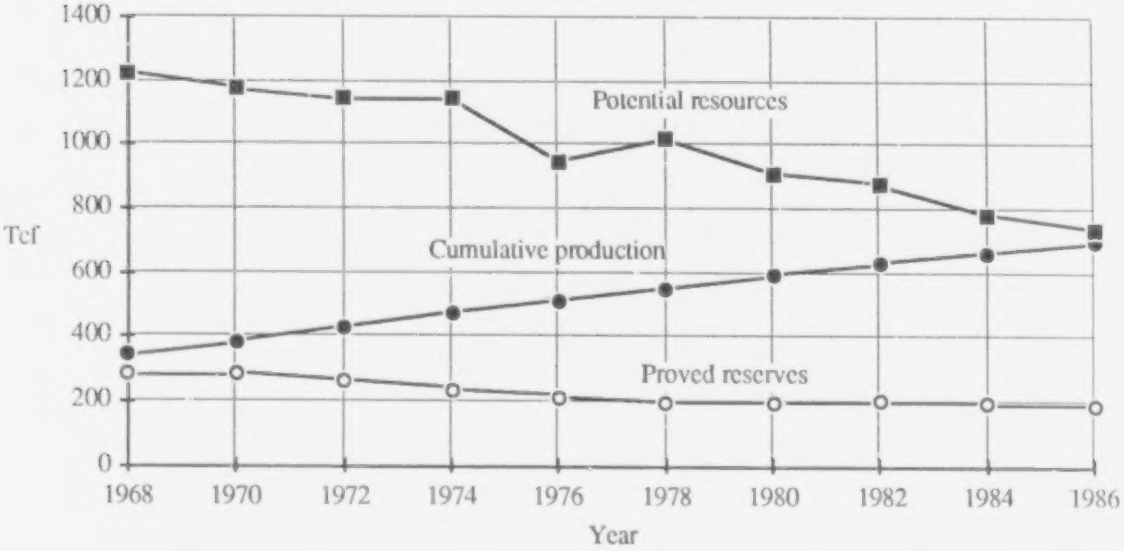

Figure 7. Biennial estimates of cumulative production, proved reserves and potential resources of natural gas in the lower 48 states

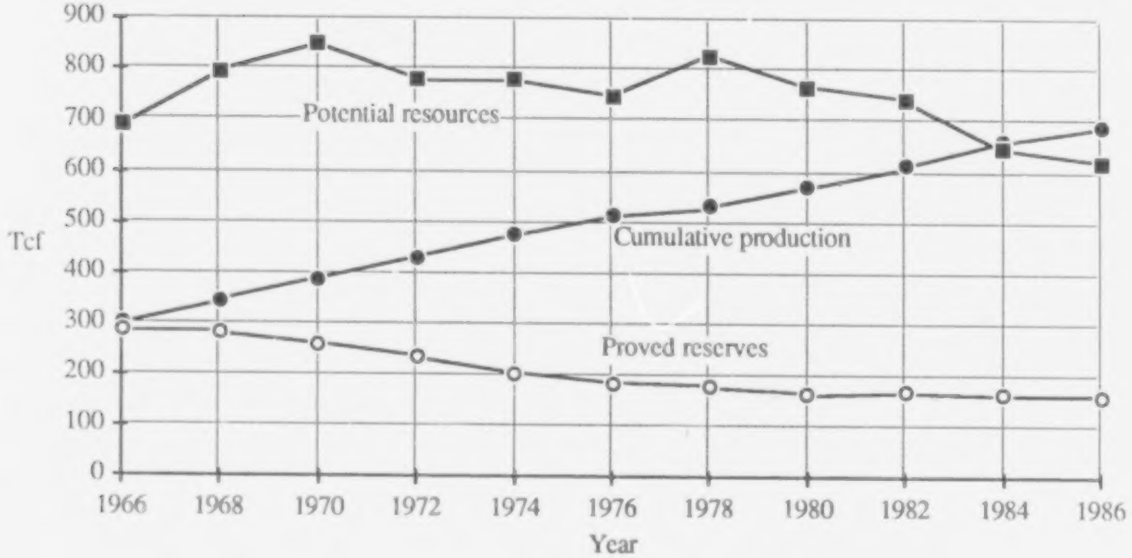

Figure 8. Estimates of ultimately recoverable resource of natural gas in the total United States

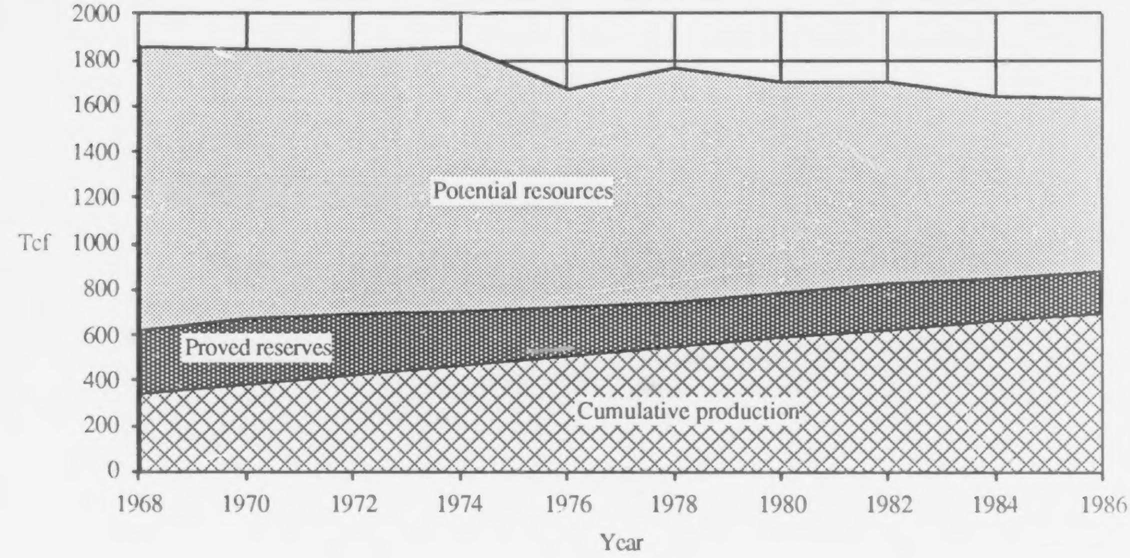

Figure 9. Estimates of ultimately recoverable resource of natural gas in the lower 48 states

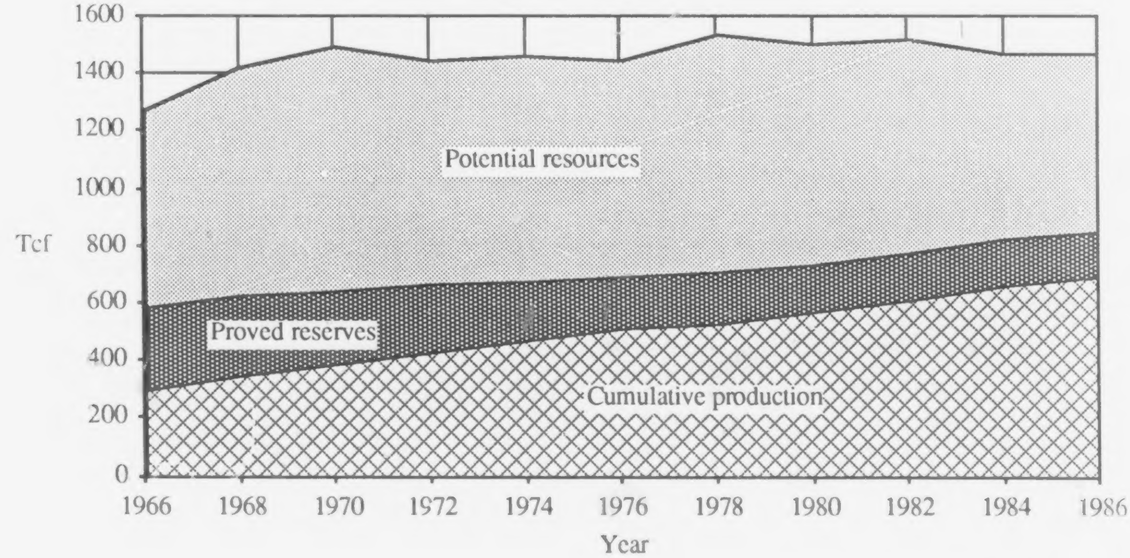

Table 9. Comparison of estimates of potential resources of natural gas from Potential Gas Committee reports (Most Likely Values--trillion cubic feet)

	PROBABLE RESOURCES	POSSIBLE RESOURCES	SPECULATIVE RESOURCES	TOTAL RESOURCES
TOTAL UNITED STATES				
As of 12-31-68	260	335	632	1,227
As of 12-31-70	257	387	534	1,178
As of 12-31-72	266	384	496	1,146
As of 12-31-76	215	363	345 to 395	923 to 973
As of 12-31-78	199	399	421	1,019
As of 12-31-80	193	358	362	913
As of 12-31-82	192	355	329	876
As of 12-31-84	185	293	306	784
As of 12-31-86	163	298	278	739
LOWER 48 STATES				
As of 12-31-66	300	210	180	690
As of 12-31-68	238	317	240	795
As of 12-31-70	218	326	307	851
As of 12-31-72	212	290	278	780
As of 12-31-76	192	318	188 to 238	698 to 748
As of 12-31-78	186	359	285	830
As of 12-31-80	185	329	254	768
As of 12-31-82	184	326	232	742
As of 12-31-84	176	264	207	647
As of 12-31-86	154	269	197	620

Table 10. Comparison of estimates, 1984 and 1986, by Area
(Most Likely Values--billion cubic feet)

AREA		PROBABLE		POSSIBLE		SPECULATIVE	
		1984	1986	1984	1986	1984	1986
ATLANTIC							
	Onshore	24,290	21,950	8,800	8,130	35,620	34,430
	Offshore	**	**	**	**	15,450	15,450
	TOTAL	24,290	21,950	8,800	8,130	51,070	49,880
NORTH CENTRAL							
	TOTAL	72	187	2,250	4,113	10,310	10,323
GULF COAST							
	Onshore	22,770	20,350	40,110	37,120	18,450	16,950
	Offshore	32,000	25,225	55,900	60,235	19,750	16,490
	TOTAL	54,770	45,575	96,010	97,355	38,200	33,440
MID-CONTINENT							
	TOTAL	46,260	47,600	88,170	90,800	58,360	62,100
ROCKY MOUNTAIN							
	TOTAL	48,345	36,551	52,996	53,283	33,400	25,466
PACIFIC							
	Onshore	1,665	1,545	6,700	6,600	6,900	6,900
	Offshore	256	237	8,913	8,913	8,828	8,828
	TOTAL	1,921	1,782	15,613	15,513	15,728	15,728
TOTAL LOWER 48 STATES		175,658	153,645	263,839	269,194	207,068	196,937
ALASKA							
	Onshore	6,700	6,590	16,400	16,400	27,690	27,690
	Offshore	2,400	2,400	12,700	12,700	71,470	53,000
	TOTAL	9,100	8,990	29,100	29,100	99,160	80,690
TOTAL UNITED STATES		184,758	162,635	292,939	298,294	306,228	277,627

**Production has not been established; no Probable or Possible resource exists.

POTENTIAL GAS COMMITTEE

NATURAL GAS RESOURCE ESTIMATES

(December 31, 1986)

The following pages comprise the Potential Gas Committee's estimate of potential natural gas resources for the United States as of December 31, 1986. The estimates are presented by Work Area and by geologic province within each Work Area.

A summary of the geology and natural gas resource potential for each geologic province is presented in order to provide the reader with brief background information about the province. This summary is not intended to be an exhaustive treatment, but rather to cover the fundamental geologic setting and its significance relative to natural gas occurrence. Information has been derived from a number of sources, especially Landes[1] and Cram.[2] Additional information has been provided in personal communication from members of the Potential Gas Committee.

Generalized stratigraphic sections have been provided for a number of the geologic provinces, especially those with significant natural gas potential. These stratigraphic sections are not necessarily accurate in all details, but they should serve to orient the reader concerning the stratigraphic position and age of reservoir and source rocks mentioned in the text. In addition to the sources listed for the geologic summaries, information for the stratigraphic sections has been derived from the published stratigraphic sections of the COSUNA project.[3]

Stratigraphic sections have been annotated to indicate those formations which are presently or potentially productive of natural gas. Formations which are currently productive of gas in commercial quantities, or have been productive of gas in the past, are indicated by an asterisk (*). Formations which, in the judgment of PGC members, have the potential to be productive of natural gas, but which are not currently productive within the province, are indicated by a pound sign (#). Other formations are not considered to be potentially productive.

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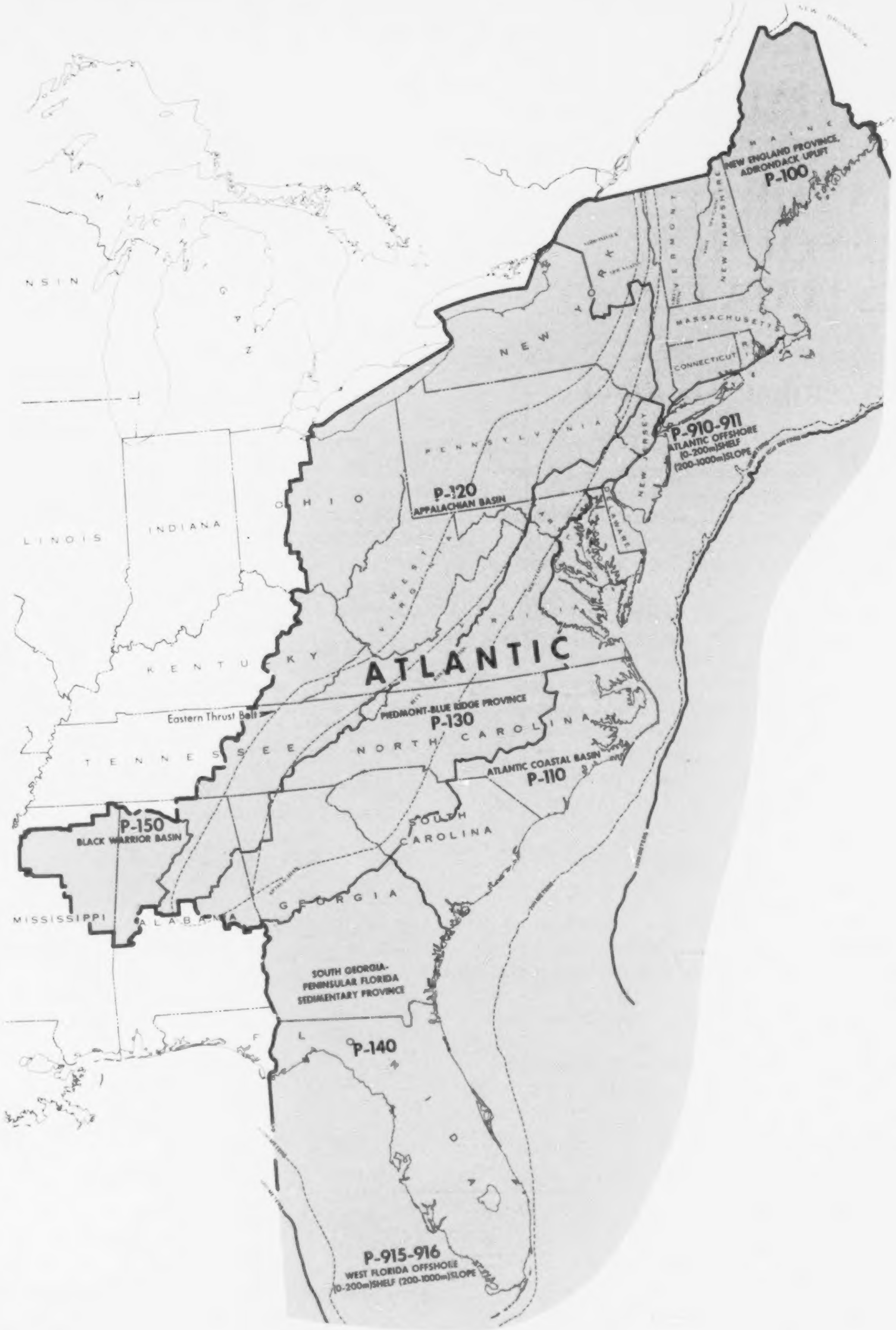
[1] Landes, K. K., 1970, Petroleum Geology of the United States: Wiley-Interscience, New York, 571 p.

[2] Cram, I. H., ed., 1971, Future Petroleum Provinces of the United States–Their Geology and Potential: American Association of Petroleum Geologists, Memoir 15, Tulsa, 1,496 p.

[3] Correlation of Stratigraphic Units of North America (COSUNA) Project: American Association of Petroleum Geologists, Tulsa.


NEW ENGLAND PROVINCE, ADIRONDACK UPLIFT
P-100
MAINE
NEW HAMPSHIRE
VERMONT
MASSACHUSETTS
CONNECTICUT
NEW YORK
PENNSYLVANIA
NEW JERSEY
DELAWARE
P-910-911
ATLANTIC OFFSHORE
(0-200m)SHELF
(200-1000m)SLOPE
P-120
APPALACHIAN BASIN
OHIO
INDIANA
ILLINOIS
WISCONSIN
MICHIGAN
WEST VIRGINIA
VIRGINIA
KENTUCKY
ATLANTIC
Eastern Thrust Belt
PIEDMONT-BLUE RIDGE PROVINCE
P-130
TENNESSEE
NORTH CAROLINA
ATLANTIC COASTAL BASIN
P-110
P-150
BLACK WARRIOR BASIN
SOUTH CAROLINA
GEORGIA
MISSISSIPPI
ALABAMA
SOUTH GEORGIA-PENINSULAR FLORIDA SEDIMENTARY PROVINCE
P-140
FLORIDA
P-915-916
WEST FLORIDA OFFSHORE
(0-200m)SHELF (200-1000m)SLOPE

ATLANTIC AREA

The only geologic provinces of the Atlantic Area which are currently productive of natural gas are the Appalachian basin and the Black Warrior basin. Other provinces which have potential for future resource development are the New England and Adirondack uplift province, the Atlantic Coastal basin, the Piedmont-Blue Ridge province, the South Georgia-Peninsular Florida sedimentary province, and the Atlantic and West Florida Offshore provinces.

P-100, NEW ENGLAND PROVINCE AND ADIRONDACK UPLIFT

This province includes the states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, Vermont and 14 counties in eastern New York State. No production of oil or natural gas has been established in this area. Sedimentary rocks in the area are predominantly of Paleozoic age, reaching a thickness of 15,000 to 20,000 feet. Additionally, there is a thick sequence of sedimentary rocks of Triassic age in the Connecticut Triassic basin. All postulated natural gas potential is located in the Connecticut Triassic basin and in the Eastern Thrust Belt which extends into eastern New York and western Vermont. Potential reservoir rocks in the Eastern Thrust Belt are of Ordovician and Cambrian age and occur both in the area of surface exposure of Paleozoic rocks (west) and the area in which the Paleozoic rocks are concealed beneath thrusted older rocks (east).

P-110, ATLANTIC COASTAL BASIN

This province includes the entire state of Delaware and portions of New Jersey, Maryland, Virginia, North Carolina and South Carolina. No production of oil or gas has been established to date. The province is bordered generally on the west by the Appalachian and Blue Ridge Mountains and includes an area of over 108,000 square miles. Sedimentary rocks range in age from Triassic(?) or Jurassic to Quaternary. Recent geophysical surveys and deep drilling have established that there are greater thicknesses of sedimentary rocks in this province than previously thought, greatly in excess of previous estimates of 10,000 feet. Potential for natural gas is believed to be limited largely to the Triassic basins, both those in which Triassic rocks are exposed at the surface and those in which younger sedimentary rocks cover the Triassic. There is also some potential in the deeper formations in the coastal areas of North and South Carolina.

P-120, APPALACHIAN BASIN

The Appalachian basin province covers an area of over 180,000 square miles in portions of the states of New York, Pennsylvania, New Jersey, West Virginia, Virginia, Maryland, Ohio, Kentucky, Tennessee, Georgia and Alabama. Its eastern border includes the Appalachian Mountains and it extends westward to the Cincinnati arch and the Nashville dome. Sedimentary rocks in the basin exceed thicknesses of 30,000 feet in places, and potential reservoir rocks range in age from Cambrian to Pennsylvanian.

Although several hundred thousand wells have been drilled in the Appalachian basin, most of them have been relatively shallow (less than 5,000 feet) and concentrated along narrow producing trends. In the entire basin, only eleven wells have been drilled to a depth deeper than 15,000 feet. Only 10-15% of the possible hydrocarbon-producing sediments have been tested and, in terms of exploration, the basin is relatively young.

Probable resources are expected to be found mostly in field extensions, infill drilling and connecting old fields. Possible resources are expected

P-110, ATLANTIC COASTAL BASIN
Generalized Stratigraphic Section

AGE	FORMATION		GENERAL LITHOLOGY
	North	South	
Cenozoic			
Quaternary	Holocene-Pleistocene deposits		sandstone and shale
Tertiary			
Pliocene	Yorktown Formation		sandstone and shale
Miocene	St. Marys Fm.-Choptank Fm.-Calvert Fm.-Hawthorn Fm.	Pungo R. Fm.	sandstone and shale
Oligocene	River Bend Fm. - Cooper Fm.		limestone, sandstone
Eocene	Nanjemoy Fm.- Pamunkey Grp.- Castle Hayne Fm.- Santee Ls. -Huber Fm. limestone		sandstone, shale,
		Black Mingo Fm.	sandstone, siltstone, shale
Paleocene	Aquia Fm.	Beaufort Fm.	sandstone and shale
Mesozoic			
Late Cretaceous	unit "A"	Peedee Fm.	shale and sandstone
	unit "B"	Black Creek Fm.	sandstone, siltstone, shale
	unit "C"		
	unit "D"	Middendorf Fm.	shale and sandstone
	unit "E"	Cape Fear Fm.	shale, siltstone, sandstone, limestone
	unit "F"		shale and sandstone
Early Cretaceous	unit "G"		shale and sandstone
	unit "H"		shale and sandstone
Jurassic (?)			red beds and basalts
Triassic (?)	Newark Grp.	unnamed red beds	red beds, sandstone, shale, siltstone
Pre-Mesozoic basement			

to be found in fields ranging in size from 5-500 Bcf with most of them being in the 15-50 Bcf range. Speculative resources are expected to be found in fields ranging in size from 50-1,000 Bcf with the most likely size being between 300-500 Bcf.

Reservoir rocks. Both detrital rocks and carbonates form potential reservoirs, and production has already been established from most potential reservoirs in at least some part of the basin. Production from Mississippian-Pennsylvanian, Devonian, Silurian, middle Late Ordovician and Cambro-Ordovician units is located, generally, along long, regional anticlinal trends that are oriented in a northeast-southwest direction. Fracturing plays an important role in the deeper reservoirs.

Traps. Stratigraphic, structural and combination traps are all abundant. Lenses, reefs and porosity variations are most important in Silurian and Mississippian reservoirs. Truncations are characteristic of Silurian-Ordovician strata. Production from widespread Devonian shales is closely related to regional fracturing patterns. Shales also form traps and seals for contained sandstone lenses. Anticlines and faulted anticlines form major traps for hydrocarbons in Devonian and Carboniferous reservoirs.

Potential source rocks. Probable source rocks for both oil and gas range from the thermally moderately mature to severely altered mid-Cambrian Rome Shale gas generators to the mid- to late -Mississippian Big Lime Formation which is a thermally moderately mature to immature source for both oil and gas. Surface seeps, tar sands and solid hydrocarbon exposures are all known from the province.

Producing trends. The central portion of the basin is basically one giant gas field, extending more than 500 miles along a northeast-southwest trend and

P-120, APPALACHIAN BASIN
Generalized Stratigraphic Section

AGE	FORMATION		GENERAL LITHOLOGY
	North	South	
Paleozoic			
Permian	*Dunkard Formation		shales, red beds
Pennsylvanian	*Monongahela Formation		shale
	*Conemaugh Formation		sandstone and shale
	*Allegheny Formation		sandstone and shale
	*Pottsville Sandstone		sandstone
Mississippian	*Mauch Chunk Formation		sandstone, shale
	*Greenbrier Limestone ("Big Lime")		limestone
	*Pocono Group		
	*Keener Sandstone		sandstone
	*Big Injun Sandstone		sandstone
	*Squaw Sandstone		sandstone
	*Weir Sandstone		sandstone
	*Berea Sandstone		sandstone
Devonian	*Catskill Fm. and *Chemung Fm.		sandstone, shale
	*Conewango Grp.		
	*Conneaut Grp.	*Bradford sands	
	*Canadaway Grp.		
	*Benson Sand		sandstone
	*Devonian shales		shale
	*Onondaga Limestone	*Huntersville Chert	limestone, chert
	*Oriskany Sandstone		sandstone
	*Helderberg Group		limestone
Silurian	*"Bass Islands"		dolomite
	Salina Fm.	Cayugan Dolomite	dolomite and evap.
	*Lockport-Guelph Fm.	*Newburg Sandstone	limestone, dolo.,ss.
		*Big Six Sandstone	sandstone
		*Keefer Sandstone	sandstone
	*Tuscarora Sandstone	*"Clinton" Fm.	sandstone, shale
	*Medina sandstones		sandstone
Ordovician	*Oswego Ss.	*upper Ordovician shale	sandstone, shale
	*Trenton-Black River Formation		limestone
	Beekmantown Dolomite	Knox Dolomite	dolomite
Cambrian/Ordovician	*Gatesburg Ss.	*Potsdam Ss. *"St. Peter" Ss.	sandstone
	*Roserun Ss.	*Rome Ss. *Weverton Ss.	sandstone
Precambrian			

*Currently producing

50 to 75 miles wide. A similar trend farther to the west parallels the giant field; here, gas production is generally more scattered in thousands of fields. This western trend defines the limit of the Appalachian basin in the west. The vast majority of the counties included within the limits of the Appalachian basin have at least some gas production. The Cambro-Ordovician Rome Formation is productive of both gas and oil at depths of almost 15,000 feet, whereas the Mississippian Berea sandstones and siltstones produce from the surface to depths of 6,100 feet.

P-130, PIEDMONT—BLUE RIDGE PROVINCE

This province covers portions of the states of Alabama, Georgia, South Carolina, North Carolina, Tennessee, Virginia, Maryland, Delaware, Pennsylvania and New Jersey, and includes an area of approximately 94,000 square miles. The province lies within the Appalachian and Blue Ridge Mountain regions and the Eastern, or Blue Ridge, Overthrust Belt is the major tectonic feature. Sedimentary rocks within the province are in excess of 30,000 feet thick and range in age from Precambrian upward, but are mainly of early Paleozoic age. No oil or natural gas production has been established in this province to date.

Reservoir rocks. Potential reservoir rocks are of Cambrian through Mississippian age. They are concealed by metamorphic rocks and granites which have been thrust from the east westward across the younger sedimentary rocks. Suspected important reservoir formations include the Cambro-Ordovician Knox Dolomite, the early Cambrian Rome Formation (shale, sandstone and dolomite) and the Precambrian to Cambrian Chilhowee Group (fractured shales).

Traps. Major anticlines within the concealed sedimentary section are interpreted from seismic cross sections and are anticipated to be the principal trapping mechanism.

Potential source rocks. The mid-Ordovician and mid-Cambrian shales are postulated to be potential source rocks for natural gas and are thermally mature. Gas shows have been reported from similar rocks to the west.

P-140, SOUTH GEORGIA—PENINSULAR FLORIDA SEDIMENTARY PROVINCE

This province covers the southern half of Georgia and most of the State of Florida with the exception of the Florida Panhandle. It is bordered on the north by the Appalachian Mountain System. The major tectonic elements include the Southeast Georgia Embayment, the northeastern portion of the Appalachicola basin, and the South Florida basin. Sedimentary rocks reach a maximum thickness of 15,000 feet. Production of oil and associated/dissolved natural gas has been established in southern Florida, but the major natural gas production in Florida is located outside of this province in the Florida Panhandle (Province P-300).

Reservoir rocks. Sedimentary rocks in the province range in age from Early Cretaceous to Tertiary and include limestones, dolomites and sandstones. Reservoir rocks for oil and associated/dissolved gas are principally Early Cretaceous limestones at depths of up to 9,000 feet.

Traps. Changes in porosity and permeability within the carbonate reservoir rocks, possibly associated with folds, are the principal trapping mechanisms.

Potential source rocks. Potential source rocks for gas and oil include the thermally immature Cedar Keys Formation (Paleocene) and the moderately mature Sunniland Limestone (Early Cretaceous).

P-150, BLACK WARRIOR BASIN

The Black Warrior basin is a triangular-shaped area located in northeastern Mississippi and northwestern Alabama. The basin extends over approximately 21,000 square miles. The Black Warrior basin is bounded on the north by the Nashville and Ozark domes, on the southeast by the Appalachian tectonic belt and on the southwest by the central Mississippi deformed belt. The sedimentary section is thicker than 20,000 feet in the deeper portion of the basin. The Black Warrior basin is currently a major producing area for natural gas, most of which is found above 6,000 feet, with only minor accumulations of oil. Recovery of natural gas associated with coal seams is becoming increasingly important.

In terms of exploration maturity, the Black Warrior basin can be divided into three areas: 1) the shallow northern and eastern portions of the basin, an area that is sparsely drilled and is considered to be immature with the potential for discovery of a number of fields of relatively small size because of both stratigraphy and depth; 2) the central portion of the basin, which is considered to be in early maturity, and holds the potential for several small- and moderate-size new field discoveries and a large number of field extensions; and 3) the southern, deeper portion of the basin which holds the potential for some intermediate- and large-size field discoveries. Sedimentary rocks in this area exceed 20,000 feet in thickness. Only seven wells have been drilled to a depth greater than 12,000 feet in the entire Black Warrior basin, and only four

P-140, SOUTH GEORGIA–PENINSULAR FLORIDA, P-915 AND P-916, WEST FLORIDA OFFSHORE, SHELF AND SLOPE

Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Miocene	Tamiami Formation	limestone and sandstone
	Hawthorn Formation	sandstone and clay
	Tampa Formation	sandy limestone
Oligocene	Suwanee Formation	limestone
Eocene	Ocala Formation	limestone
	Avon Park Formation	limestone
	Lake City Formation	limestone
	Oldsmar Formation	limestone
Paleocene	#Cedar Keys Formation	dolomite and anhydrite
Mesozoic		
Cretaceous		
Late	Gulf Series	
	Lawson Limestone	limestone
	Atkinson Formation	limestone and shale
Early	Comanchean Series	
	limestone	limestone
	"upper anhydrite unit"	anhydrite
	*Sunniland Limestone	limestone, dolomite
	Glades Creek Gp.	
	Punta Gorda Fm.	anhydrite
	#Lehigh Acres Fm.	
	Able Mbr.	limestone, anhydrite
	Twelve Mile Mbr	limestone, dolomite
	"brown dolomite zone"	
	West Felda Shale	shale
	Coahuilan Series	
	Fort Pierce Group	
	Pumpkin Bay Fm.	limestone, anhydrite, dolomite
	Bone Island Fm.	anhydrite, limestone; dolomite
Jurassic	Wood River Formation	anhydrite, dolomite, limestone, basal clastic unit
Triassic-Jurassic		rhyolite, basalt

*Currently producing #Potentially productive

P-150, BLACK WARRIOR BASIN
Generalized Stratigraphic Section

AGE	FORMATION NE Mississippi	FORMATION NW Alabama	GENERAL LITHOLOGY
Cenozoic			
Tertiary			
Eocene	Claiborne Group		
	Cockfield Formation		sandstone
	Cook Mountain Formation		shale
	Sparta Sandstone		sandstone
	Tallahatta Formation		sandstone, shale
	Wilcox Formation		sandstone, shale
Paleocene	Midway Group		shale
Mesozoic			
Upper Cretaceous	Selma Group		
	Prairie Bluff Chalk		chalk
	Owl Creek Formation		marl
	Ripley Formation		shale
	Demopolis Chalk		chalk
	Mooreville Chalk --	Coffee Sand	chalk, sandstone
	Eutaw Formation		shale, sandstone
	Tuscaloosa Group		sandstone
Lower Cretaceous	undifferentiated		
Paleozoic			
Pennsylvanian		Boyles Sandstone	sandstone
	*Pottsville Formation		sandstone, shale
Mississippian			
	*Chester Series	#Parkwood Fm.	shale, sandstone, limestone
		#Gardner Ss. Mbr.	
	#Buskirk Sandstone	#Gilmer Ss. Mbr.	
	#Millerella Limestone	#Millerella Ls. Mbr.	
	#Carter Sandstone	#Bangor Ls. Mbr.	
	*Sanders Sandstone		
	#Rea Sandstone		
	#Abernathy Sandstone		
	Neal Black Shale	#Hartselle Sandstone	
	Floyd Shale		shale
	#Evans Ss. Mbr.		sandstone
	#Lewis Sandstone		sandstone
Meramac Series	#Tuscumbia Limestone		limestone
	#Ft. Payne Formation		chert
Devonian	#undifferentiated		
Silurian	#undifferentiated		
Cambrian	#undifferentiated		

*Currently producing #Potentially productive

wells have been drilled below 15,000 feet. The interaction of structure, stratigraphy and diagenesis in the deeper portion of the Black Warrior basin is relatively unknown and will control the size and number of fields discovered.

Reservoir rocks. Production in the Black Warrior basin is primarily from Paleozoic clastics of the Mississippian Chester series. The sandstones of the Pennsylvanian Pottsville series also produce some hydrocarbons. Potential reservoir rocks range from Precambrian to Pennsylvanian age and consist of sandstones, limestones, dolomite and chert.

Traps. Hydrocarbon traps in the Black Warrior basin are primarily combination traps involving anticlines, faulted anticlines, high-angle normal faults and stratigraphy. Channel and bar sandstones provide stratigraphic traps in the Chester and Pottsville series. Stratigraphic traps usually have a structural component. Porosity variations in the carbonate sequences provide potential traps for hydrocarbons alone or in combination with structure and faulting.

Potential source rocks. The Mississippian Chester series is thermally mature to very mature and provides sources for both gas and oil. The thermally mature Pennsylvanian Pottsville series and the mature to very mature Ordovician Black River group would probably be sources primarily for gas.

P-910 AND P-911, ATLANTIC OFFSHORE, SHELF AND SLOPE

These provinces cover the entire Atlantic offshore area of the United States. Major tectonic features include the Yarmouth arch, Georges Bank basin, Baltimore Canyon Trough, Southeast Georgia Embayment, the Carolina trough and platform, Blake Plateau basin, South Florida-Bahamas basin, and the Peninsular arch of Florida. No natural gas or oil production has been established in the province, although the existence of moderate quantities of gas has been established in at least one area. The accumulation of gas discovered was not sufficient to warrant installation of production facilities. Even though results to date have not been encouraging, numerous concepts and plays remain unevaluated and present some possibility for the existence of natural gas resources. Considering the size of the Atlantic offshore area and the sparsity and uneven distribution of wells, the province must still be considered immature from the standpoint of exploration. If production is established, the fields would have to be intermediate to large size in order to justify commercial development.

Potential reservoir rocks. Sedimentary rocks, mainly of Mesozoic to Tertiary age, are 30,000 feet or more thick. Sandstones and limestones are the major potential reservoir rocks. Limestones are more important in the southern portion of the province and perhaps are more important in the farther offshore areas of the Slope Province.

Traps. A large variety of trapping mechanisms have been postulated to occur, including most principal types of both stratigraphic and structural traps. Carbonate environments, including reefs if present, could include stratigraphic traps due to reef structures and permeability changes. Truncations and pinchouts may be related to some clastic reservoirs. Salt domes are also believed to be present. Structural traps may include both faults and folds.

Potential source rocks. Potential source rocks in the central portion of both provinces are anticipated to be more favorable for natural gas generation than for oil. Prospects for oil generation, along with gas, are more favorable in the northern (Georges Bank) and southern (Southeast Florida Shelf) regions.

P-915 AND P-916, WEST FLORIDA OFFSHORE, SHELF AND SLOPE

The western Florida shelf extends about 150 miles into the Gulf of Mexico. Many of the stratigraphic units of onshore peninsular Florida extend into this offshore area. Cretaceous and Tertiary rocks comprise the majority of the 25,000-30,000 feet of sediment in this area. Carbonate rocks are the major constituent in most of the province. Clastic rocks were deposited in the north. Probability is good for continuation of trends from the eastern part of the Gulf Coast Province and the panhandle region of Florida; additionally, trends which are productive predominantly of oil in south Florida may also extend offshore and include some natural gas resources. No hydrocarbons are presently being produced in the province. The west Florida offshore area is extremely large and there is virtually no information available from drilling which is applicable to these provinces. If natural gas production is established in the area, it would be anticipated that the fields would be intermediate to large size.

Potential reservoir rocks. The southern part of the province, which lies in the South Florida basin, appears to offer prospects for large-scale production. The Lehigh Acres Formation (Lower Cretaceous) is the best prospect because of the thick and highly porous Brown Dolomite zone in the Twelve Mile Member. The Sunniland Formation, which is productive onshore, will not prove economically feasible offshore unless it has a thicker porous section than is found onshore. Other formations which are of lowermost Cretaceous and upper Jurassic age may prove to be productive, but to date the porosity and geochemistry found in these formations onshore have not been favorable.

In the northern portion of the province, there is potential for the extension offshore of the productive trends of southern Mississippi, southern Alabama and northwestern Florida. Possible reservoir units in the area are the Upper Cretaceous Tuscaloosa Formation, the Lower Cretaceous Hosston Formation, and the Upper Jurassic Smackover Formation.

Traps. Possible trapping mechanisms include reefs in the Upper Cretaceous and porosity changes in carbonate and sandstone facies. Anticlines, faulted anticlines and salt domes may exist.

Potential source rocks. Likely source rocks for the southern part of the area are closely associated with the carbonate rocks which are also potential reservoir rocks. Potential source rocks for the northern part include the Tuscaloosa and Smackover Formations along with the Lower Cretaceous Gordo Formation and Jurassic Cotton Valley Formation.

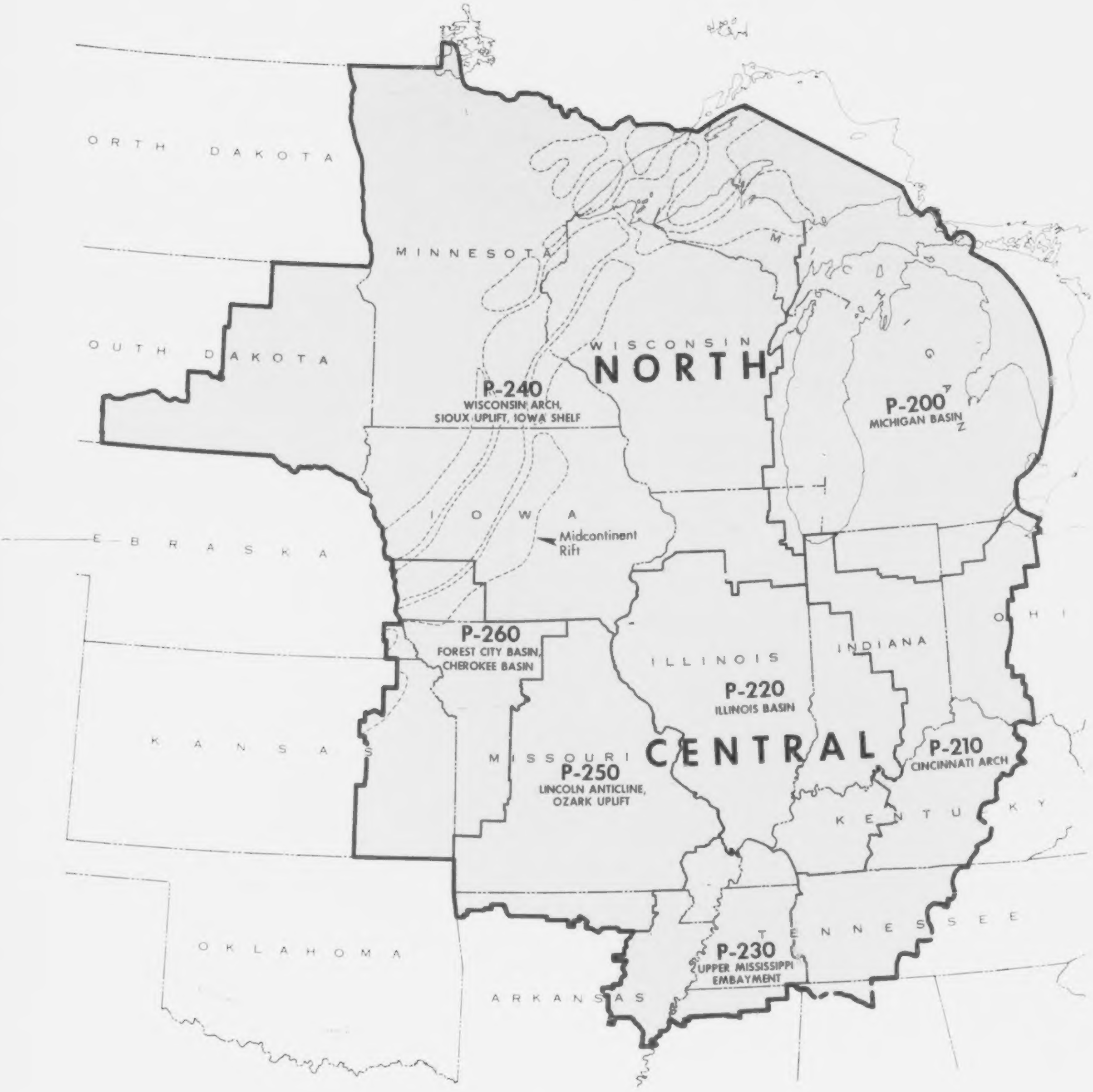
P-910 and P-911, ATLANTIC OFFSHORE, SHELF AND SLOPE
Generalized Stratigraphic Section

AGE	FORMATION		GENERAL LITHOLOGY
	North	South	
Cenozoic			
Pleistocene	Laurentian Formation	unnamed sands, silt and clay	sandstone, siltstone, clay
Pliocene-Miocene	Banquereau Formation		sandstone, siltstone clay
Oligocene-Eocene-Paleocene	unnamed limestone	unnamed mudstone and chalk	limestone, mudstone, chalk
Mesozoic			
Late Cretaceous	Dawson Canyon Fm.	unnamed siltstone and shale	shale, mudstone, siltstone
Early Cretaceous	Missisauga Fm. Baccaro ls.	unnamed sandstone shale, limestone	sandstone, limestone
Jurassic	Mic Mac-Mohawk Fm. Mohican Fm. Iroquois Fm.	evaporites	siltstone evaporites limestones
Triassic	conglomerate Argo Salt	unnamed sandstone, siltstone, shale	conglomerate, sandstone, shale, siltstone
Paleozoic and Precambrian	metamorphic complex		

Table 11. Estimated resources of natural gas for provinces of the Atlantic Area, December 1986 (billion cubic feet)

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPECULATIVE		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-100, New England and	0-15,000'								1,850	660	*
Adirondack uplift	15-30,000'								*	*	*
P-110, Atlantic Coastal	0-15,000'								1,450	440	*
basin	15-30,000'								*	*	*
P-120, Appalachian	0-15,000'		34,490	21,490	14,850	24,630	7,420	3,580	55,140	19,410	6,230
basin	15-30,000'								17,640	4,920	500
P-130, Piedmont-Blue	0-15,000'								5,980	2,070	500
Ridge province	15-30,000'								11,000	4,540	920
P-140, South Georgia-	0-15,000'								960	340	*
Peninsular Florida	15-30,000'								1,450	500	*
P-150, Black Warrior	0-15,000'		900	460	170	670	310	100	1,000	450	*
basin	15-30,000'					860	400	150	3,320	2,320	*
P-910, Atlantic shelf		0-200 m							33,000	13,200	*
P-911, Atlantic slope		200-1,000 m							*	*	*
P-915, West Florida shelf		0-200 m							4,000	1,590	*
P-916, West Florida slope		200-1,000 m							6,000	660	*
TOTAL, onshore	0-15,000'			21,950			8,130			23,370	
TOTAL, onshore	15-30,000'			*			*			11,060	
TOTAL, onshore, all depths				21,950			8,130			34,430	
TOTAL, offshore		0-200 m		*			*			14,790	
TOTAL, offshore		200-1,000 m		*			*			660	
TOTAL, offshore, all depths				*			*			15,450	
GRAND TOTAL FOR AREA				21,950			8,130			49,880	

*Negligible quantity of natural gas estimated


ORTH DAKOTA
MINNESOTA
OUTH DAKOTA
WISCONSIN
NORTH
MICHIGAN
P-240
WISCONSIN ARCH, SIOUX UPLIFT, IOWA SHELF
P-200
MICHIGAN BASIN
IOWA
Midcontinent Rift
EBRASKA
P-260
FOREST CITY BASIN, CHEROKEE BASIN
ILLINOIS
INDIANA
OHI
P-220
ILLINOIS BASIN
KANSAS
MISSOURI
P-250
LINCOLN ANTICLINE, OZARK UPLIFT
CENTRAL
P-210
CINCINNATI ARCH
KENTUCKY
TENNESSEE
OKLAHOMA
P-230
UPPER MISSISSIPPI EMBAYMENT
ARKANSAS

NORTH CENTRAL AREA

The estimated resource potential for the North Central area in the Probable and Possible categories occurs entirely in the Michigan basin. Potential resources in the Speculative category are also estimated to occur in the Michigan basin, and in addition are postulated for the Cincinnati arch province, the Illinois basin, the Upper Mississippi Embayment and the Forest City-Cherokee basins.

The Michigan basin has good exploratory potential for both structural and stratigraphic traps having small- to intermediate-size accumulations of gas. One or more giant fields are possible. The deep Cambro-Ordovician formations are now being tested in the basin. The evaluation of new data has resulted in an increase in the most likely estimate of Potential resources for the Michigan basin.

The Cincinnati arch province is generally well explored, but has the potential of the occurrence of small accumulations of either structurally or stratigraphically trapped resources. The Illinois basin is a maturely explored oil basin, and potential gas accumulations will likely be small. Many of the larger shallow structures have been tested into the older formations without encouragement. Devonian shale gas awaits technical and economic incentives for the development of this resource into intermediate-sized fields. The Upper Mississippi Embayment is an unexplored province with potential for intermediate-sized structural and stratigraphic traps. The Wisconsin arch-Iowa shelf is sparsely explored because of the relatively thin stratigraphic section consisting mostly of Paleozoic rocks. However, the postulated Mid-Continent Rift Zone indicated by geophysical information may contain intermediate to giant-sized structural traps. It has yet to be proven whether natural gas might be found in these traps. The Lincoln anticline-Ozark uplift province is a structurally high area with Precambrian rock outcrops and does not appear to have natural gas potential. The Forest City basin has been moderately drilled and explored. Potential traps may be either structural or stratigraphic with the accumulations of natural gas most likely to be of small size.

P-200, MICHIGAN BASIN

The Michigan basin geologic province includes the state of Michigan and portions of northern Indiana, northwestern Ohio, northeastern Illinois, and eastern Wisconsin. The province is bordered on the north and east by the Canadian border, on the west by the Wisconsin arch and on the south by the Kankakee and Findlay arches. The basin is an almost perfectly circular structural basin. Precambrian crystalline rocks outcrop around the northern rim of the basin. Erosion has not uncovered Precambrian rocks around the southern rim, but formations as old as Ordovician are exposed in Ohio and Indiana. In the center of the basin, Precambrian rock lies at a depth of 18,000 feet or more. The youngest widespread bedrock formations are Jurassic and Pennsylvanian sediments which occur toward the center of the basin. These bedrock formations are overlain by up to 1,200 feet of glacial sediments. The sedimentary rocks within the basin consist predominantly of Paleozoic carbonate rocks with some sandstones. Production of both natural gas and oil has been established from many fields within the basin.

Since 1929, approximately 42,000 wells have been drilled within the Michigan Basin, the majority of which have tested relatively shallow formations (less than 6,000 feet) along anticlinal trends within the central basin area. Since 1980 there have been 150 wells drilled deeper than 8,000 feet with 66 holes drilled below 10,000 feet.

The Lower Ordovician Prairie du Chien Group is a relatively new exploration target which has yielded significant new deep gas reserves in the central basin area. Only 1,400 wells have tested this horizon with the majority of these drilled in the shallow, less prospective southern flank of the basin. Approximately 20-25% of the known shallow structures in the central basin area have been tested through the Lower Ordovician.

Generally, the sediments shallower than 6,000 feet are in a mature stage of exploration and offer

P-200, MICHIGAN BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Quaternary		glacial deposits
Mesozoic		
Jurassic		red beds
Paleozoic		
Pennsylvanian		sandstone, shale, coal
Mississippian	Michigan Formation	shale, anhydrite, dolomite
	*"Stray" Sandstone	sandstone
	Marshall Sandstone	sandstone
	Coldwater Shale	shale
	*Weir Sand	sandstone
	Berea Sandstone	sandstone
Devonian	*Ellsworth-Antrim Shale	shale
	*Traverse Group	limestone and shale
	Rogers City-Dundee Limestones	limestone-dolomite
	Reed City	dolomite and evaporites
	Detroit River Group	
	Lucas Formation	dolomite and evaporites
	Sour Zone	dolomite
	*Richfield	dolomite and evaporites
	Amherstburg Formation	limestone
	Sylvania Sandstone	sandstone
	Bois Blanc Formation	limestone
Silurian	Bass Islands Dolomite	dolomite
	Salina Formation	evaporites, shales and carbonates
	E Unit	carbonates
	Kintigh Zone	dolomite
	*A_2 Carbonate	limestone and dolomite
	*A_1 Carbonate	limestone and dolomite
	*Niagara Carbonates	dolomite-limestones
	*Burnt Bluff Group	dolomite-limestones
Ordovician	Richmond Group	shales and carbonates
	*Trenton-Black River Limestones	limestone
	*St. Peter Sandstone	sandstone
	*Prairie du Chien Group	dolomite and sandstone
Cambrian	#Trempealeau Formation	limestone
	#Eau Claire Formation	sandstone
	#Munising Sandstone	sandstone
	Jacobsville Sandstone	sandstone
Precambrian		granite and crystalline rocks

* Currently producing   # Potentially productive

little potential for substantial new gas discoveries. Sediments deeper than 6,000 feet offer the greatest potential for new gas discoveries.

The resources included in the Probable category will be found in field development and extensions. Possible gas resources are expected to be found in fields ranging in size from 2-100 Bcf with most of them estimated to be in the 5-20 Bcf range. The resources classified as Speculative are expected to be found in fields ranging from 1-50 Bcf with the most likely size between 5-25 Bcf.

A portion of the Speculative potential for the Michigan basin lies beneath waters of the Great Lakes (maximum: 545 Bcf; most likely: 269 Bcf; minimum: 54 Bcf). These areas are currently withdrawn from exploration and development. The estimated potential for these offshore areas is included within the estimate for the total Michigan basin.

Reservoir rocks. Currently productive and potential reservoir rocks range from the early Ordovician (Prairie du Chien) sandstones to the Mississippian (Berea, "Stray" and Marshall sandstones). Dolomites and sandstones are the principal potential reservoir rocks, and all potential reservoirs from the early Ordovician to the Carboniferous are already productive of gas or oil. Central basin formations of Silurian, early Ordovician and Cambrian age, including sandstones and dolomites, are potential reservoirs.

Traps. Reefs are common traps in Silurian (Niagaran) and in Devonian (Traverse) strata. Porosity and permeability variations also form traps in Ordovician, Devonian and Mississippian-Pennsylvanian lithologies. Anticlines and faulted anticlines form traps in Silurian, Devonian and Mississippian-Pennsylvanian beds. Secondarily dolomitized fracture trends accumulate major oil and gas reserves in middle Ordovician carbonates.

Potential source rocks. Potential source rocks for natural gas are predominantly Devonian shales and carbonate rocks (Antrim and Bell Shales, Traverse Group carbonates). The Salina A_1 Carbonate is the most likely source for Silurian reef gas accumulations. The Middle Ordovician Trenton-Black River carbonates are also considered to be a potential hydrocarbon source.

Producing trends. The Niagaran reef trend, the Albion-Scipio type fracture trends and the Prairie du Chien sands are the principal gas producing areas to date. Production generally is from less than 8,000 feet. Gas occurs in the lower Ordovician Prairie du Chien at depths as great as 11,630 feet primarily along anticlinal trends in the central basin area.

P-210, CINCINNATI ARCH

The Cincinnati arch is a wide area of uplift which stretches from Ohio and Indiana southward through Kentucky and Tennessee into northernmost Alabama. The northern portion of the arch splits east and west into two branches which wrap around the southern end of the Michigan basin. The western branch is known as the Kankakee arch and the eastern as the Findlay arch. The southern end of the Cincinnati arch is somewhat separated from the remainder by an area in southern Kentucky, known as the Cumberland saddle, in which the axis of the arch plunges downward. The southernmost portion, south of the Cumberland saddle, is known as the Nashville dome. The Appalachian basin lies to the east and the Illinois basin to the west. The Cincinnati arch complex began its major upwarping in the Silurian Period. The crest is wide and the dips are exceptionally gentle. Most of the accumulations of gas and oil in western Ohio occur along the structurally highest part of the Findlay arch. Sedimentary rocks in the province range in age from Cambrian to Pennsylvanian and are relatively thin. Natural gas and oil production have been established in all of the states of this province.

The great Lima-Indiana field of eastern Indiana and western Ohio was discovered in 1884. Maximum production from this field was reached in 1896.

Reservoir rocks. Productive and potential reservoir rocks for gas and oil range in age from Cambro-Ordovician to Mississippian. The most common reservoir rocks are limestones and dolomites. Apart from the Devonian Salina-Niagaran Groups, all prospective reservoirs are already productive. The western Ohio fields on the Findlay arch produce chiefly from the Trenton Formation of Ordovician age. Trenton and Black River Limestones (Ordovician) are the principal reservoir formations in northern and eastern Indiana. Silurian carbonate rocks are the most prolific reservoirs in Kentucky, including the Lego (Louisville), Laurel and Brassfield, but production has also been found in Middle Devonian limestones and sandstones, the Ordovician Trenton-Black River-Chazy and the Cambro-Ordovician. Tennessee fields produce from Mississsippian, Silurian and Ordovician limestones.

Traps. Production in the Trenton-Black River Limestones is due to irregularly distributed dolomitization porosity enlarged by weathering before subsequent submergence. The principal traps in the Silurian reservoirs of Kentucky occur where porosity zones have been truncated by erosion and sealed by the deposition of the Devonian New Albany (Chattanooga) Shale immediately above the unconformity. Some Ordovician production is from fracture porosity, and there are some reef limestones encased in younger shales. Accumulation in Tennessee appears to be due to varying permeability within the reservoir rocks and to the presence of small folds.

Source rocks. Late Cambrian, Mississippian, and Pennsylvanian shales are considered to be fair to good sources for natural gas.

P-220, ILLINOIS BASIN

This province includes most of the state of Illinois and portions of western Kentucky and Indiana. The province is bounded on the north by the Kankakee arch, on the east by the Cincinnati arch complex and on the south by the Pascola arch. To the west the basin is bounded by the Mississippi River arch-Lincoln anticline. The province is predominantly an oil-producing province, but some natural gas is produced in small quantities. Sedimentary rocks consist primarily of Paleozoic sandstones and limestones which reach a thickness of at least 20,000 feet in the deepest part of the basin.

Reservoir rocks. Reservoirs for oil and gas exist in rocks of Cambro-Ordovician to Pennsylvanian age. Lithologies vary from sandstone to limestone and dolomite. Apart from the Devonian New Albany Shale, all potential reservoir rocks are already productive of oil or gas. The principal production comes from Pennsylvanian sandstones, Mississippian Chester sandstones, Ste. Genevieve, St. Louis and Salem Limestones, and the Ordovician Trenton-Galena Limestone.

Traps. Although there are many examples of stratigraphic traps in which there is no structural closure and the up-dip edge of the reservoir is sealed by porosity attenuation, some of the most prolific production in the basin has come from reservoirs in which there is continuous porosity and permeability across the tops of anticlines and other structural highs. Relatively minor fractions of the basin's production is associated with faults and Silurian reefs.

Potential source rocks. Potential source rocks for both gas and oil range in age from Cambrian to Pennsylvanian. Thermally, they range from immature to very mature. Among the good potential sources are the middle Ordovician Guttenberg Limestone, the late Ordovician Maquoketa Shale and the Devonian-Mississippian New Albany Shale. Seeps, tar sands and other shows are present.

P-230, UPPER MISSISSIPPI EMBAYMENT

This province includes portions of northeastern Kansas, southeastern Missouri, northern Mississippi, western Kentucky and western Tennessee. The province is bounded on the south by the Black Warrior and Desha basins, on the west by the Arkoma basin, on the north by the Illinois basin and on the east by the Nashville Dome. No gas or oil production has been established in this region to date. Sedimentary rocks in this province are predominantly Paleozoic sandstones and carbonate rocks which may reach a maximum thickness of 20,000 feet.

P-220, ILLINOIS BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Paleozoic		
Pennsylvanian	Mattoon Formation	sandstone, shale
	Bond Formation	shale, limestone, sandstone
	Modesto Formation	shale, sandstone
	*Carbondale Formation	shale, ls, coal, ss.
	*Spoon Formation	sandstone, shale, coal
	*Abbott Formation	sandstone
	*Caseyville Formation	sandstone
Mississippian	*Chesterian Series	sandstone, limestone, shale
	Valmeyeran Series	
	*Aux Vases Formation	sandstone, limestone
	*Ste. Genevieve Limestone	limestone
	*St. Louis Limestone	limestone, dolomite
	*Salem Limestone	limestone, dolomite
	Ullin Limestone	limestone
	*Borden Formation	siltstone, sandstone
	Chouteau Limestone	limestone
	(Rockford Limestone)	
Devonian	#New Albany Shale	shale
	Lingle Formation	limestone, dolomite
	Cedar Valley Group	sandstone
	*Grand Tower Formation	limestone, dolomite
	Dutch Creek Sandstone Member	sandstone
	Clear Creek Limestone	limestone
	Backbone Limestone	limestone
	Bailey Limestone	limestone
Silurian	*Moccasin Springs Limestone	limestone
	St. Clair Limestone	limestone
	*Kankakee Limestone	limestone
	*Edgewood Limestone	limestone, dolomite
Ordovician	Maquoketa Shale	shale, limestone, dolomite
	*Trenton/Galena Limestone	limestone, dolomite
	Guttenberg Limestone	limestone
	Platteville Limestone	limestone, dolomite
	Joachim Dolomite	dolomite
	Dutchtown Limestone	limestone
	St. Peter Sandstone	sandstone
	Prairie du Chien Gp./ Knox Dolomite	dolomite
	Gunter Sandstone	sandstone
Cambrian	Eminence Formation	dolomite, sandstone
	Potosi Dolomite	dolomite
	Franconia Formation	sandy carbonates
	Galesville Sandstone	sandstone
	Eau Claire Formation	shale and carbonate
	Mt. Simon Sandstone	sandstone
Precambrian		crystalline rocks

*Currently producing #Potentially productive

P-240, WISCONSIN ARCH, SIOUX UPLIFT AND IOWA SHELF

This province includes the states of Minnesota and Wisconsin and portions of South Dakota, Iowa and northern Illinois. The province is bounded on the north by the Canadian border, on the east by the Michigan basin, on the south by the Forest City basin, and on the west by the Siouxana and Chadron arches and the Williston basin. No production of natural gas or oil has been established to date. Sedimentary rocks are predominantly Paleozoic carbonate rocks and sandstones and probably are generally less than 15,000 feet thick. Recent exploration interest has been focused on the Mid-Continent Rift Zone which traverses the province from northeast to southwest. It is postulated that considerable thicknesses of sedimentary rocks were deposited along this tectonic trend in elongate fault-block basins which may contain potential reservoir and source rocks. The faulting which is associated with the rift zone may have originated in Precambrian time and continued to affect Paleozoic sedimentation as well.

P-250, LINCOLN ANTICLINE AND OZARK UPLIFT

This province includes portions of Missouri and northern Arkansas. It is bounded on the east by the Lincoln anticline/Mississippi River arch, on the south by the Arkoma basin and on the northwest by the Forest City basin. In total, it encompasses an area of more than 53,000 square miles. No production of natural gas or oil has been established. Sedimentary rocks of Paleozoic age predominate. In most places the section of sedimentary rocks is thin and basement rocks of Precambrian age are not deeply buried.

P-260, FOREST CITY BASIN AND CHEROKEE BASIN

This province includes an area of more than 63,000 square miles and covers portions of eastern Kansas, southeastern Nebraska, southwestern Iowa and northwestern Missouri. It is bordered on the southwest by the Nemaha uplift, on the southeast by the Ozark uplift, and on the east by the Mississippi River arch/Lincoln anticline. Currently non-associated gas production has been established in the Kansas portion of the Forest City basin and both oil and gas production in the Cherokee basin and the Missouri portion of the Forest City basin. Sedimentary rocks consist mainly of Paleozoic sandstones and limestones which are up to 20,000 feet thick.

Reservoir rocks. Production of natural gas and oil stems dominantly from Mississippian and Pennsylvanian sandstones and carbonate rocks. The Siluro-Devonian "Hunton" Limestone and the mid-Ordovician Viola/Simpson Limestones are productive of oil in the Forest City basin. Potential reservoir rocks range in age from Cambrian to Pennsylvanian. Sandstones and carbonate rocks are equally important as potential reservoirs.

Traps. Stratigraphic and structural traps are small, but equally abundant, in Pennsylvanian and pre-Pennsylvanian reservoirs. Stratigraphic trap types include porosity and lithology changes, onlaps, sandstone lenses, channels and bars. Structural trap types include both anticlines and faulted anticlines.

Potential source rocks. The thermally immature to mature Pennsylvanian Cherokee Shale and some Mississippian shales and limestones are thought to be good potential sources for both natural gas and oil. The same is true for the Devonian-Mississippian Chattanooga Shale which is thermally mature.

P-260, FOREST CITY AND CHEROKEE BASINS
Generalized Stratigraphic Section

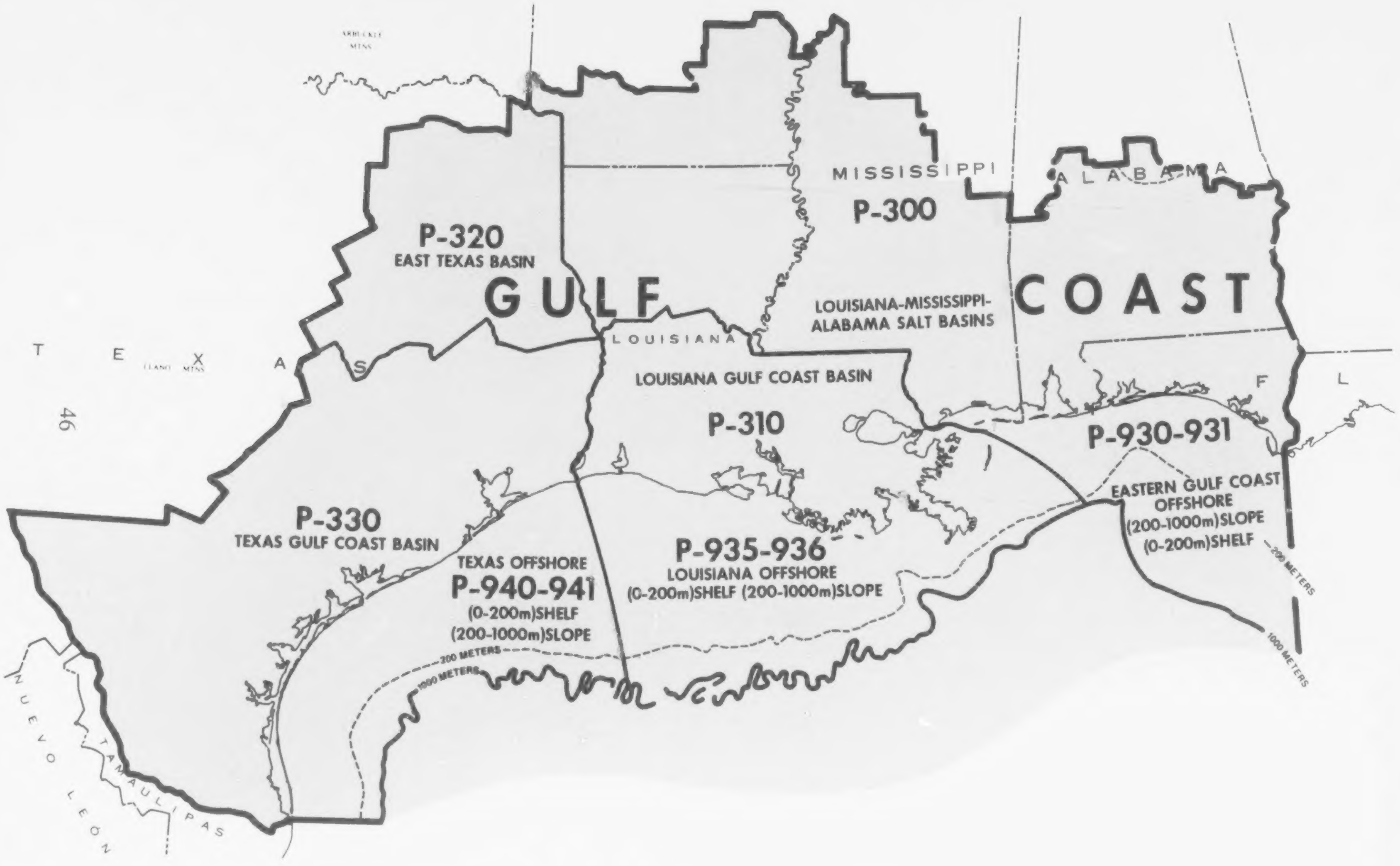
AGE	FORMATION	GENERAL LITHOLOGY
Paleozoic		
Permian		red beds and evaporites
	Chase Group	limestone and shale
	Council Grove Group	limestone
	*Admire Group	shale, limestone, sandstone
Pennsylvanian	*Wabaunsee Group	limestone and shale
	*Shawnee Group	shale, sandstone, limestone
	*Douglas-Pedee Groups	shale, sandstone
	*Lansing-Kansas City Groups	limestone, sandstones, shales
	*Pleasanton Group	sandstone and limestone
	*Marmaton Group	limestone, shale, sandstone
	*Cherokee Group	sandstone and shale
	*Atokan Group	limestone and shale
	*Morrowan Group	shale, limestone, sandstone
Mississippian	*"Mississippian Chert"	chert, limestone
	*"Mississippian Lime"	limestone
Mississippian-Devonian	#Chattanooga Shale	shale
Devonian	*Misener Sandstone	sandstone
Siluro-Devonian	#"Hunton" Limestone	dolomite
Ordovician	Maquoketa Shale	shale
	#Viola Limestone	limestone and sandstone
	*Simpson Sandstone	sandstone
Cambro-Ordovician	Arbuckle Group	dolomite, limestone, shale
	Reagan Sandstone	sandstone
Precambrian		granite and crystalline rocks

*Currently producing #Potentially productive

Table 12. Estimated resources of natural gas for provinces of the North Central Area, December 1986 (billion cubic feet)

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPECULATIVE		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-200, Michigan basin	0-15,000'		330	187	116	7,862	4,113	1,135	1,035	474	82
	15-30,000'								*	*	*
P-210, Cincinnati arch	0-15,000'								7,139	2,499	1,428
	15-30,000'								*	*	*
P-220, Illinois basin	0-15,000'								15,610	4,900	1,350
	15-30,000'								*	*	*
P-230, Upper Mississippi	0-15,000'								4,220	1,450	450
Embayment	15-30,000'								*	*	*
P-240, Wisconsin arch,	0-15,000'								*	*	*
Sioux uplift, Iowa shelf	15-30,000'								*	*	*
P-250, Lincoln anticline,	0-15,000'								*	*	*
Ozark uplift	15-30,000'								*	*	*
P-260, Forest City basin,	0-15,000'								1,500	1,000	500
Cherokee basin	15-30,000'								*	*	*
TOTAL, onshore	0-15,000'			187			4,113			10,323	
TOTAL, onshore	15-30,000'			*			*			*	
TOTAL, onshore, all depths				187			4,113			10,323	
GRAND TOTAL FOR AREA				187			4,113			10,323	

*Negligible quantity of natural gas estimated


ARBUCKLE MTNS
LLANO MTNS
TEXAS
46
P-320
EAST TEXAS BASIN
GULF
COAST
LOUISIANA
MISSISSIPPI
ALABAMA
FL
P-300
LOUISIANA-MISSISSIPPI-ALABAMA SALT BASINS
LOUISIANA GULF COAST BASIN
P-310
P-930-931
EASTERN GULF COAST OFFSHORE
(200-1000m)SLOPE
(0-200m)SHELF
P-330
TEXAS GULF COAST BASIN
TEXAS OFFSHORE
P-940-941
(0-200m)SHELF
(200-1000m)SLOPE
P-935-936
LOUISIANA OFFSHORE
(0-200m)SHELF (200-1000m)SLOPE
200 METERS
1000 METERS
NUEVO LEON
TAMAULIPAS

GULF COAST AREA

All of the geologic provinces of the Gulf Coast Area are productive of natural gas and oil. This region is the dominant producing area of natural gas in the United States. Much of the area is in a mature exploration stage, but important new fields continue to be discovered. Many of the reservoir rocks are highly porous and permeable and capable of delivering high volumes of gas. Much of the major natural gas pipeline system is designed to transport gas from this area to northern and eastern regions of the country.

In the Gulf Coast Area several changes have been made in resource estimates. Developments in the Eastern Gulf of Mexico, shelf and slope (provinces P-930 and P-931), as well as adjacent onshore regions in the Louisiana-Mississippi-Alabama Salt Basins Province (P-300), related to the Lower Mobile Bay Norphlet play, have resulted in re-evaluation of the natural gas potential for this region. Estimates of most likely Probable resources have been increased slightly with a corresponding decrease in some estimates of Possible and Speculative resources. The study demonstrated that a much larger portion of the shelf (P-940) resources should be classified as Possible rather than Probable, with the total most likely estimate remaining essentially unchanged.

In the Texas Offshore, shelf and slope provinces (P-940 and P-941), have been completely reevaluated in view of the fields discovered to date and additional data available as a result of the newly instituted area-wide leasing programs. The most likely estimate of Probable resources for P-941 was reduced because only three fields are currently under development. However, the estimate of Possible resources was increased based on the new data. The slope province is still in the early stages of exploration, and the large portions of the shelf province have been only sparsely drilled.

P-300, LOUISIANA-MISSISSIPPI-ALABAMA SALT BASINS

This region is bounded on the northwest by the Ouachita Mountains and on the northeast and east by the Paleozoic Black Warrior basin and southern extent of the Eastern Thrust Belt. It contains three structural uplifts: the Sabine uplift, the LaSalle uplift, and the Monroe uplift. Other structural elements in the area include the Jackson Dome, an igneous intrusion in central Mississippi; the Hatchtigbee anticline; and the Pickens-Gilbertown-Pollard fault zone which is an extension of the Mexia-Talco fault zone of the East Texas basin. Northeast-southwest trending faults flank the east side of the Sabine uplift. The region contains more than 80 salt domes, and has many other salt-deformation-related features. It is a region of major production of oil, non-associated gas and associated/dissolved gas. A wide belt of gas fields extends from high on the Monroe uplift to the Texas border.

The gas found in deeper drilling in older fields, along with field extensions and new pool tests, is included in the Probable resource estimates. Possible resources will be found in fields of 40 to 600 Bcf with an average range of 60 to 100 Bcf. Speculative resources will be found in fields of 100 Bcf to 1 Tcf with the most likely field size of 200 to 500 Bcf of gas.

Reservoir rocks. Reservoir rocks range in age from Jurassic to Miocene. Tertiary reservoir rocks are undifferentiated Miocene zones, the Eocene Cane River Formation of the Claiborne Group, and the Wilcox Formation. Upper Cretaceous reservoir units are the Taylor and Navarro Formations of the Selma Group, the Austin Chalk and Eagle Ford Shale of the Eutaw Formation and the Tuscaloosa Group. Productive Lower Cretaceous intervals are the Washita Formation, the Paluxy, Rodessa, James Lime, Sligo, and Hosston Formations of the Trinity Group. The upper Jurassic reservoir rocks are the Cotton Valley Group including the Schuler

P-300, LOUISIANA-MISSISSIPPI-ALABAMA SALT BASINS
Generalized Stratigraphic Section

AGE	FORMATION		
	Louisiana	Mississippi	Alabama
Cenozoic			
Quaternary			
Pleistocene			
Tertiary			
Pliocene		#Citronelle Formation	
Miocene		#Pascagoula/Hattiesburg	*Miocene-undiff.
		#Catahoula Sandstone	
Oligocene			#Vicksburg Group
Eocene		*Jackson Group	
	*Claiborne Group	*Claiborne Group	#Claiborne Group
	*Wilcox Group	*Wilcox Formation	#Wilcox Group
Paleocene	#Midway Group	#Midway Group	#Midway Group
Mesozoic			
Cretaceous			
Late (Gulfian)	*Selma Group	*Selma Group	*Selma Group
	*Eutaw Group	*Eutaw Formation	*Eutaw Formation
	*Tuscaloosa Group	*Tuscaloosa Group	*Tuscaloosa Group
Early (Comanchean)	*Washita/Fredericksburg	*Washita/Fredericksburg	*Washita/Fredricksburg
	*Trinity Group	*Trinity Group	*Trinity Group
	*Sligo Formation		
	*Hosston Formation	*Hosston Formation	*Hosston Formation
Jurassic	*Cotton Valley Group	*Cotton Valley Group	*Cotton Valley Group
	*Smackover Formation	*Smackover Formation	*Smackover Formation
	#Norphlet Formation	#Norphlet Formation	*Norphlet Formation
	Louann Salt	Louann Salt	Louann Salt
	#Werner Formation		
Triassic	#Eagle Mills Formation	#Eagle Mills Formation	#Eagle Mills Formation
Paleozoic			
Permian	#Morehouse Formation		
Pennsylvanian			

* Currently producing # Potentially productive

Formation, the Smackover Formation and Norphlet Formation. The Upper Cretaceous units are the most prolific reservoirs in the northern portion of the province. In the Louisiana portion, the Wilcox is the Formations are important gas horizons in the sub-basin between the Sabine and Monroe uplifts. The Monroe "Gas Rock" of the Selma Group is the major gas producer on the Monroe uplift.

Traps. Trapping in the region is largely associated with salt deformation. This includes salt domes, truncations, sandstone onlap on to structures, and anticlines. Fault associated traps are very important around salt domes, around the Jackson dome, along the east side of the Sabine uplift, and in the Pickens-Gilbertown-Pollard fault zone. Production from fault traps is frequently on the upthrown block. Lenticular sandstones are common throughout the region. Reefs occur in the Washita Formation. A major regional unconformity exists between the Upper Cretaceous and Lower Cretaceous. Several smaller unconformities also form traps in the province.

Source rocks. Source rocks range in age from Tertiary to Jurassic. Tertiary source rocks are the Claiborne Group, Wilcox Formation, and Midway Formation. Cretaceous source rocks include the Selma Group, Eutaw Formation, Tuscaloosa Group and Hosston Formation. Jurassic source rocks include the Cotton Valley Group and Smackover Formation and downdip facies of the Norphlet.

Trends. Major producing trends in the area are located in the Wilcox, Tuscaloosa, Cotton Valley, Smackover and Norphlet Formations.

P-310, LOUISIANA GULF COAST BASIN (ONSHORE)

The Louisiana Gulf Coast basin is one of the major oil and gas provinces in the United States. It is the lower part of the Mississippi Embayment. Most of the province is covered by Quaternary sediments, but Tertiary rocks outcrop in the northern portion. An extremely thick clastic wedge of fluvial and deltaic sediments was deposited. Regional structure is largely the result of differential sedimentation related to salt flowage and the associated contemporaneous faulting. Salt domes are abundant and both salt and sulfur are mined.

The South Louisiana onshore basin is one of the most extensively explored areas in the United States. A large percentage of the hydrocarbons found to date above 15,000 feet have been crude oil with dissolved and associated gas caps. Some 90 percent of the significant anticlinal or fault closures above 15,000 feet have been tested by one or more wells.

Gas discoveries in recent years have found fields ranging in size from 2 to 150 Bcf with average size of some 8 Bcf. Size of future discoveries above 15,000 feet will likely average less than the 8 Bcf. Resources classified as Speculative will be found in fields varying in size from 2 to 500 Bcf with average being 30 to 50 Bcf.

Reservoir rocks. South Louisiana produces from Tertiary through Cretaceous rocks. Tertiary reservoirs are mainly sandstones capped by shales of Miocene, Oligocene and Eocene age. Cretaceous reservoirs are largely oil-bearing carbonates, but significant gas is present in Tuscaloosa sands and Sligo carbonates. The thick Miocene wedge dominates South Louisiana in both oil and gas production.

Traps. The major trapping mechanisms in this province are faulted anticlines and salt domes. A high percentage of these traps are fault-related. Truncations with overlaps influence some reservoirs. Many stratigraphic traps, including updip porosity wedgeouts, occur in the Cretaceous carbonates.

Source rocks. Thick, organic-rich, Cretaceous and Tertiary shales provide ample sources for hydrocarbons in this prolific province.

Trends. Starting with the Lower Cretaceous in the northern portion of the province, the major trends parallel the coastline in bands of progressively younger sediments in the following sequence: Lower Tuscaloosa, Wilcox, Oligocene, Lower Miocene, Middle Miocene and Upper Miocene.

P-310, LOUISIANA GULF COAST BASIN (ONSHORE)
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Quaternary		
Pleistocene		
Tertiary		
Pliocene		
Miocene	*Fleming Formation	shale, sandstone
	*Upper	
	*Middle–"Harang"	
	*Lower–"Abbeville"	
Oligocene	*Anahuac Formation	shale, sandstone
	*Frio Formation	sandstone, shale
	*"Hackberry"	
	*"Shuteston"	
	Vicksburg Group	sandstone, shale, marl
Eocene	Jackson Group	sandstone, shale
	Yazoo Formation	shale
	Moody's Branch Marl	marlstone
	Claiborne Group	sandstone, shale
	*Cockfield Formation	sandstone and shale
	Cook Mountain Formation	shale
	*Sparta Formation	sandstone
	Cane River Formation	shale
	*Wilcox Group	sandstone, shale
Paleocene	Midway Group	sandstone, shale
Mesozoic		
Cretaceous		
Late	Selma Group	limestone and sandstone
	Eutaw Group	sandstone and shale
	*Tuscaloosa Group	sandstone
Early	#Washita/Fredericksburg	limestone
	#Trinity Group	ss. shale, anhydrite, limestone
	#Sligo Formation	limestone
	#Hosston Formation	sandstone and shale

* Currently producing # Potentially productive

P-320, EAST TEXAS BASIN

The East Texas basin, or Tyler basin, occupies northeastern Texas. It is bounded on the north and west by the Ouachita Tectonic Belt and is separated from the North Louisiana basin to the east by the Sabine uplift. The Angelina-Caldwell flexure separates it from the Texas Gulf Coast basin to the south. The East Texas basin is part of the Mississippi Embayment. Upper Cretaceous rocks outcrop in the western and northwestern portions of the basin. Progressively younger rocks outcrop to the south and east. The two most prominent structural features in the basin are the Mexia-Talco fault system which parallels the Ouachita Tectonic Belt on the west and north margins of the basin and the Sabine uplift to the east. The Mexia-Talco system extends eastward into the Louisiana-Mississippi-Alabama salt basin. The Mt. Enterprise fault system extends westward from the southern flank of the Sabine uplift to near the central portion of the basin. Several regional unconformities occur in this basin. There are also numerous salt domes, salt anticlines and related residual or "turtle back" structures.

The East Texas Basin is a maturely explored basin. Resources included in the Probable category will be found in field extensions and infield drilling. The Possible category resources will likely be found in fields ranging in size from 5-50 Bcf. The Speculative category resources probably will be found in fields ranging in size from 20-500 Bcf.

Reservoir rocks. Production ranges in age from Jurassic to Eocene. The only Tertiary production is from sandstones in the Wilcox Group. The Upper Cretaceous production is from the Taylor Group, the Austin Chalk, the Eagle Ford and Woodbine Groups. Lower Cretaceous reservoir rocks are the Buda Formation of the Washita Group, members of the Fredricksburg Group, the Paluxy Formation, members of the Glen Rose Formation, the Rodessa and James Formations of the Glen Rose Group and the Pettet and Travis Peak Formations of the Nuevo Leon Group. Jurassic reservoir rocks are both sandstones and limestones in the Cotton Valley Group and the Smackover Formation. Paleozoic sandstones and limestones are potential reservoirs in the northern and western portions of the basin.

Traps. Combination structural-stratigraphic traps are very common throughout the province and affect most of the stratigraphic intervals. Anticlines, faulted anticlines and faults are the most common structural mechanisms, particularly in the Woodbine and Smackover. High energy sand and carbonate facies, in combination with various structures, form traps in the Tertiary, Upper and Lower Cretaceous units and portions of the Jurassic. Reef facies form traps in the James Limestone. Salt domes are less important as traps in the basin. Local and regional unconformities also form traps, the most notable of which is the East Texas field.

Source rocks. It is likely that the source rocks for this province are shales that are adjacent to the various reservoirs. Limestones in parts of the area are possible sources as are transgressive shales overlying unconformities.

Trends. Notable trends in this basin are the Mexia-Talco Fault zone, the Smackover trend which generally parallels the Mexia-Talco trend but lies farther downdip and two Cotton Valley Limestone trends, one of which occurs in an arcuate pattern around the western flank of the Sabine uplift and the other trends along the southwestern portion of the basin. Most of the major Upper and Lower Cretaceous producing formations occur basin-wide and are not situated in trends.

P-330, TEXAS GULF COAST BASIN (ONSHORE)

The Texas Gulf Coast basin covers 67 counties of southern and southeastern Texas. It encompasses part of the Mississippi Embayment and part of the Rio Grande Embayment. It is bounded on the north and west by the Balcones Fault zone and Ouachita Tectonic Belt. Much of the production in this region is from Tertiary reservoirs. This is one of the major hydrocarbon regions of the United States. Both associated/dissolved and non-associated gas are produced in this region.

Resources classified as Possible are expected to be found in fields of size 3-30 Bcf with most being in the 10-15 Bcf range. Resources classified as

Speculative are expected to be found in fields varying in size from 10-100 Bcf with the most likely size being 20-40 Bcf.

Reservoir rocks. Tertiary reservoir rocks are the Fleming, Anahuac, Frio, Vicksburg, Jackson Group, Claiborne Group, Wilcox Group and Midway Group. The Frio is the leading reservoir in the southern Gulf Coast area. Upper Cretaceous reservoir units include the Navarro Formation, Taylor Group, Austin Chalk, Eagle Ford Formation and Woodbine Formation. Lower Cretaceous reservoir rocks are the Buda and Georgetown Limestone Members of the Washita Formation, the Edwards Limestone and Paluxy Members of the Fredericksburg Formation, the Rodessa Member of the Glen Rose Formation and the Sligo Limestone. All productive formations produce both oil and gas except the Lower Cretaceous Sligo and Glen Rose Formations which produce only gas

Traps. Anticlines, domes, diapirs and faults are the most common trapping mechanisms in the region and affect all productive intervals. Salt diapirs are more common in the northern portion, whereas shale diapirs are more common in the southern portion. Stratigraphic traps are less common, but sandstone lenses, sandstone pinchouts across structures and updip pinchouts do exist in the region. Overpressured reservoirs exist on shallow salt domes as well as at deeper levels. Some Frio structures host in excess of 50 sandstone reservoir units. Reefs occur in the Cretaceous, producing primarily non-associated gas.

P-320, EAST TEXAS BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Tertiary		
Eocene	Claiborne Group	sandstone and shale
	*Wilcox Group	shale and sandstone
Paleocene	Midway Group	shale and sandstone
Mesozoic		
Cretaceous		
Late (Gulfian)	Navarro Formation	sandstone and shale
	*Taylor Formation	limestone
	*Austin Formation	shale, limestone, sandstone
	*Eagle Ford Shale	shale
	*Woodbine Sandstone	sandstone
Early (Comanchean)	*Washita Formation	limestone and shale
	*Fredericksburg Limestone	limestone
	*Paluxy Formation	sandstone
	*Trinity Group	
	*Glen Rose Formation	limestone, shale, anhydrite
	Ferry Lake Formation	anhydrite
	*Rodessa Formation	sandstone and shale
	*James Formation	limestone
	*Pettit Formation	limestone
Jurassic	*Cotton Valley Group	sandstone, limestone, shale
	Buckner Formation	limestone
	*Smackover Formation	limestone
	Luann Formation	salt
Triassic (?)	Eagle Mills Formation	salt and shale
Paleozoic	#undifferentiated	sandstone, limestone

* Currently producing # Potentially productive

P-330, TEXAS GULF COAST BASIN (ONSHORE)

Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Quaternary		
Pleistocene		
Tertiary		
Pliocene		
Miocene	Fleming Formation	shale, sandstone
Oligocene	*Anahuac Formation	shale, sandstone
	*Frio Formation	sandstone, shale
	*Vicksburg Group	sandstone, shale, marl
Eocene	*Jackson Group	sandstone, shale
	*Claiborne Group	sandstone, shale
	*Wilcox Group	sandstone, shale
Paleocene	#Midway Group	sandstone, shale
Mesozoic		
Cretaceous		
Late (Gulfian)	Navarro Formation	shale, sandstone
	*Taylor Group	chalk, marl, sandstone, silt
	*Austin Chalk	chalk
	Eagle Ford Shale	shale
	*Woodbine	sandstone
Early (Comanchean)	Washita Formation	limestone, shale
	*Fredericksburg Formation-	
	*Edwards Limestone	limestone, dolomite
	Paluxy	shale, sandstone
	Trinity Group	
	*Glen Rose Formation	limestone
	Pearsall Formation	shale, limestone
	#Sligo Limestone	limestone, dolomite
	#Hosston Formation	sandstone, limestone, dolomite
Jurassic	Cotton Valley Group	shale, sandstone
	#Smackover Formation	limestone
	#Norphlet Formation	sandstone, red beds
	Louann Formation	salt
	Werner Formation	anhydrite
Triassic	#Eagle Mills Formation	sandstone, shale
Paleozoic		
Permian	#Morehouse Formation	shale, sandstone
Pennsylvanian		

* Currently producing # Potentially productive

Source rocks. All intervals from Tertiary to Lower Cretaceous contain likely source rocks. Most of these are bituminous shales, but limestones and chalks are also sources in the region.

Trends. Numerous trends exist in this province. They lie subparallel with both the Ouachita Tectonic Belt and the present day coast and overlap one another. Proceeding from west to east are: the Cretaceous trend, the Wilcox trend, the Queen City-Yegua trend, the Vicksburg-Frio trend and the Miocene trend, which extends offshore. The Cretaceous Edwards reef trend overlaps the Eocene Wilcox trend.

P-930 AND P-931, EASTERN GULF COAST OFFSHORE, SHELF AND SLOPE

The Eastern Gulf Coast shelf has excellent potential for future discoveries. The probabilty is high for continuation of trends offshore from Mississippi, Alabama and the Florida Panhandle. Discoveries to date have been confined to the area offshore from Mobile Bay.

The resources classified as Possible are expected to be found in fields ranging in size from 50-750 Bcf with most of them being in the 100 Bcf range. The resources classified Speculative will be found in fields ranging in size from 50-1000 Bcf with the most likely size being between 100-200 Bcf.

Reservoir rocks. Possible reservoir rocks in this region are the Upper Cretaceous Tuscaloosa Formation, the Lower Cretaceous Hosston Formation and the upper Jurassic Cotton Valley Formation, Smackover Formation and Norphlet Formation. Minor Miocene reservoirs are also recognized at this time.

Traps. Anticlines, faults, faulted anticlines and deep-seated salt swells are the most likely traps in this area. Porosity changes are the most likely stratigraphic trap. Regional unconformities may also form traps in this area.

Source rocks. The most probable source rocks in this region are the Upper Cretaceous Tuscaloosa Formation, Lower Cretaceous Gordo Formation, Jurassic Cotton Valley Formation and unrecognized downdip rocks.

P-935 AND P-936, LOUISIANA OFFSHORE, SHELF AND SLOPE

This region is the most prolific offshore area of the United States. The shelf is only twenty miles wide at the end of the Mississippi delta, but widens to 130 miles near the Texas Gulf Coast boundary. The upper slope, as well as the shelf, is very productive in this province. East-west trending fault zones probably extend from onshore out onto the shelf. Pressures encountered in the reservoirs may be much higher than normal.

Reservoir rocks. Reservoir rocks in this area are all sandstones. They range in age from Pleistocene through Miocene. Older units are buried to great depth and are not productive to date. Individual formation names are not applied in the offshore region. Paleontologic markers are the most commonly utilized means of identifying the stratigraphic units. Many of the units are debris flows and submarine fans.

Traps. Salt domes, growth faults and faulted anticlines are the most common trapping mechanisms in this region. Onlaps and truncations are very common. Porosity changes in the deeper reservoirs and lenticularity of the sand bodies form effective traps.

Source rocks. The source rocks for this region are bituminous shales ranging in age from Miocene through Pleistocene.

Trends. The Miocene-Pliocene Fleming Trend extends from onshore, continuing offshore, to near the shelf-slope break. The Pleistocene trend starts near the Mississippi River mouth and extends on down the continental slope.

P-940 AND P-941, TEXAS OFFSHORE, SHELF AND SLOPE

The Texas Offshore portion of the Gulf Coast is an important hydrocarbon producing province. The majority of production to date has been natural gas and most of the undrilled prospects are thought to be gas-prone.

The Texas shelf and slope provinces were completely reevaluated in view of area-wide leasing and fields discovered to date. The study confirmed the previous total estimate for the shelf, but demonstrated a much larger proportion should be included in Possible. Although Possible for the slope remains essentially unchanged, Probable was reduced significantly because only three fields are currently being developed with which Probable resources can be associated. To date, less than 5,000 wells have been drilled in the shelf area of 15 million acres and exploration on the slope is in its early stages. Resources classified as Possible are expected to be found in fields ranging in size from 15-400 Bcf with most of them being in the 20-50 Bcf range.

Potential in this region is excellent, but less than that for offshore Louisiana. Since this area is farther from the Mississippi delta complex, there is a higher percentage of shale in the section and the sandstones are finer-grained. Strong longshore currents during the Tertiary period had a destructive effect on the Texas Gulf Coast deltaic deposition with the resulting formation of an extensive barrier bar system. Quaternary deposits were influenced by sea level fluctuations with channel and turbidite environments predominant in proximity to the slope. Permeabilities and porosities vary in all age strata because of the diverse depositional environments.

Reservoir rocks. Producing units for the Texas Gulf shelf and slope are not designated by formation names. They are simply referenced by geologic age. The productive formations range in age from Oligocene to Pleistocene. Productive intervals range from as shallow as 2,000 feet to in excess of 15,000 feet.

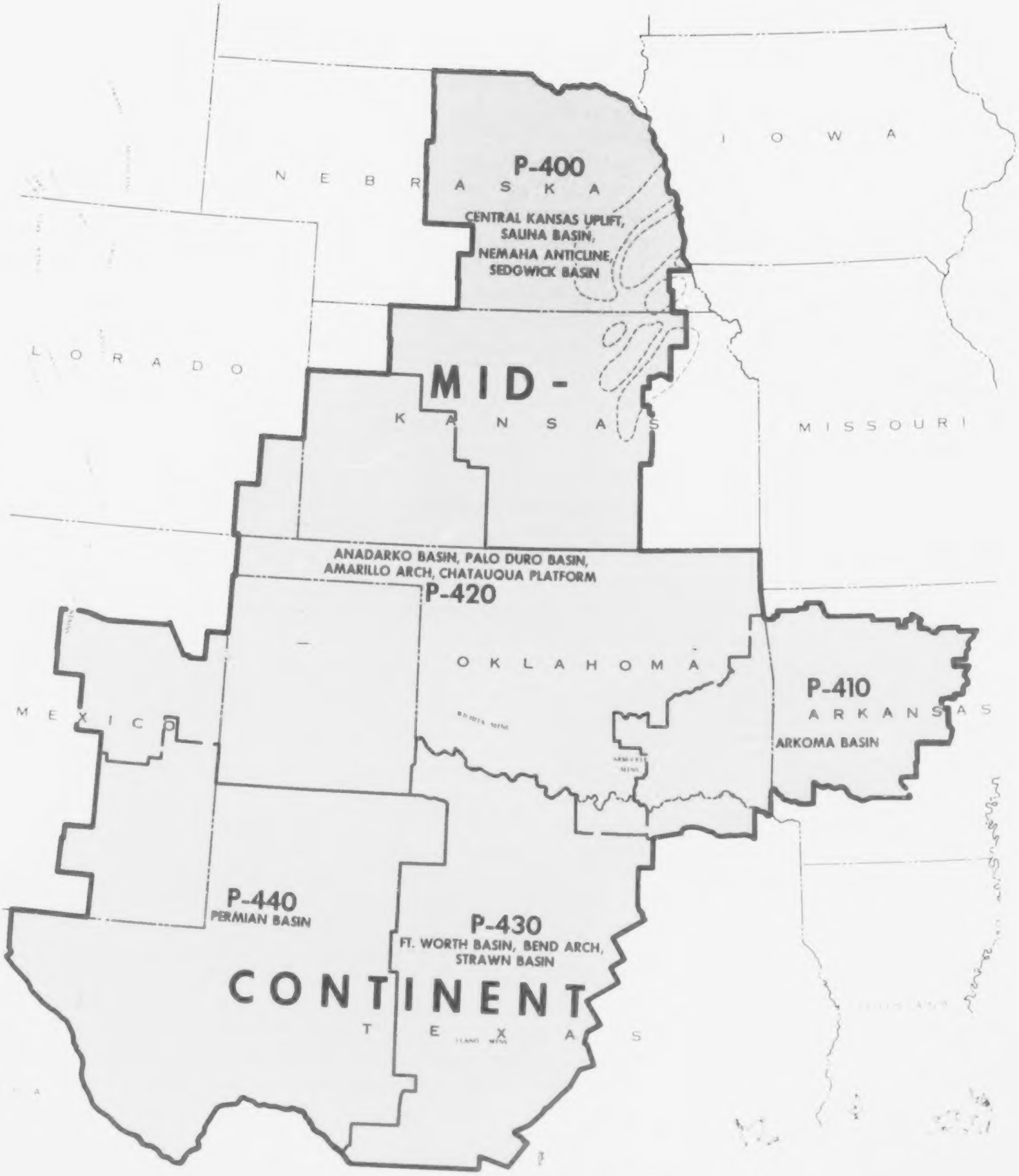
Traps. Anticlines, faulted anticlines, shale diapirs, shallow and deep-seated salt intrusions and growth faults are the major trapping mechanisms in this province. Stratigraphic traps include sandstone lenses, onlap, truncations and porosity variations.

Source rocks. Miocene shales are the probable source rocks for this province. It is hypothesized that vertical migration accounts for the hydrocarbon accumulation in the younger Plio-Pleistocene rocks.

Table 13. Estimated resources of natural gas for provinces of the Gulf Coast Area, December 1986 (billion cubic feet)

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPECULATIVE		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-300, Louisiana-Mississippi-	0-15,000'		6,580	4,490	3,180	8,540	5,750	2,880	5,180	3,070	340
Alabama salt basins	15-30,000'		1,580	1,160	430	13,720	9,270	4,460	17,680	11,430	830
P-310, Louisiana Gulf Coast	0-15,000'		3,640	3,060	2,100	2,760	2,160	460	*	*	*
basin (onshore)	15-30,000'		4,780	3,960	2,800	9,030	6,910	2,030	1,000	450	*
P-320, East Texas basin	0-15,000'		1,100	750	400	1,600	900	300	*	*	*
	15-30,000'		80	50	40	150	80	20	1,500	1,000	500
P-330, Texas Gulf Coast	0-15,000'		3,650	2,550	450	7,250	6,850	2,650	1,000	500	*
basin (onshore)	15-30,000'		5,490	4,330	3,180	7,200	5,200	4,000	1,200	500	250
P-930, Eastern Gulf shelf		0-200 m	3,240	2,025	1,035	18,950	7,950	2,650	1,000	7,000	2,500
P-931, Eastern Gulf slope		200-1,000 m	*	*	*	4,300	2,000	400	12,750	8,500	*
P-935, Louisiana shelf		0-200 m	19,700	17,300	10,400	29,600	17,200	4,400	*	*	*
P-936, Louisiana slope		200-1,000 m	2,500	1,400	400	22,500	12,800	3,800	*	*	*
P-940, Texas shelf		0-200 m	6,025	4,330	2,275	19,275	15,425	10,325	750	500	*
P-941, Texas slope		200-1,000 m	225	170	65	7,320	4,860	2,050	730	490	200
TOTAL, onshore	0-15,000'			10,850			15,660			3,570	
TOTAL, onshore	15-30,000'			9,500			21,460			13,380	
TOTAL, onshore, all depths				20,350			37,120			16,950	
TOTAL, offshore		0-200 m		23,655			40,575			7,500	
TOTAL, offshore		200-1,000m		1,570			19,660			8,990	
TOTAL, offshore, all depths				25,225			60,235			16,490	
GRAND TOTAL FOR AREA				45,575			97,355			33,440	

*Negligible quantity of natural gas estimated


P-400
NEBRASKA
CENTRAL KANSAS UPLIFT,
SALINA BASIN,
NEMAHA ANTICLINE,
SEDGWICK BASIN
IOWA
LORADO
MID-
KANSAS
MISSOURI
ANADARKO BASIN, PALO DURO BASIN,
AMARILLO ARCH, CHATAUQUA PLATFORM
P-420
OKLAHOMA
P-410
ARKANSAS
ARKOMA BASIN
MEXICO
P-440
PERMIAN BASIN
P-430
FT. WORTH BASIN, BEND ARCH,
STRAWN BASIN
CONTINENT
TEXAS

MID-CONTINENT AREA

The Mid-Continent Area is, next to the Gulf Coast Area, the most important area of current natural gas production in the country. The Area includes the Permian basin, the Anadarko basin and the extensive Hugoton-Panhandle area, all of which are important gas-producing areas and have great potential for natural gas exploration and development. Additionally, the Arkoma basin and the Fort Worth basin-Bend arch-Strawn basin provinces are believed to have significant gas potential.

Almost all of the provinces of the Mid-Continent Area are in a mature stage of exploration. It is expected that most future fields to be discovered will fall into small or intermediate size categories. The two exceptions to this generalization are the deeper portions of the Anadarko basin and portions of the Arkoma basin where extensive exploration has not yet occurred.

Re-evaluation of the resource potential for the Mid-Continent Area has resulted in some increases in estimates for two provinces. Based on additional resources which are being developed by increasing the density of wells drilled, the most likely estimates for all resource categories have been increased for the Arkoma basin (province P-410). Most likely estimates of resources for the deep portion of the Anadarko basin in Province P-420 have been increased based on restudy of available data.

P-400, CENTRAL KANSAS UPLIFT, SALINA BASIN, NEMAHA ANTICLINE AND SEDGWICK BASIN

This province covers eastern Nebraska and central Kansas. Paleozoic rocks outcrop in much of the region. Lower Cretaceous rocks cover part of the western portion and Cenozoic rocks mantle parts of Nebraska. It is primarily an oil province, but both non-associated and associated/dissolved gas are produced. Most of the production in this province is along the Central Kansas uplift. The Salina basin is the least explored portion of the region. (Production is shallow--not more than 5,000 feet deep.)

Reservoir rocks. Producing horizons range in age from Cambrian to Permian. Carbonate rocks of the Cambrian-Ordovician Arbuckle Group contain the major oil reservoirs in the region. Most of the gas, however, is recovered from upper Paleozoic units. Pennsylvanian-age rocks are very important reservoirs. They include the Lansing-Kansas City Group, the Cherokee Group and basal sandstone/conglomerate. Other important reservoirs are the Permian Chase-Admire Group; the Mississippian "Mississippi Lime"; the Devonian Cooper Formation; the Silurian-Devonian "Hunton" Limestone; the Silurian Chimneyhill Limestone; the Ordovician Viola Limestone and Simpson Sandstone; and the Cambrian Reagan Sandstone.

Traps. Anticlines, faulted anticlines and domes form traps for all intervals throughout the province. Unconformity truncations affect Pennsylvanian and older units. In the Reagan Sandstone and Arbuckle Group, buried topographic relief provides a trapping mechanism. Traps are formed in lower Pennsylvanian units by onlap onto older structures. Variations in porosity affect both carbonate and sandstone units. Sandstones take the form of channel complexes, bars, and sheet sands.

Potential source rocks. The province is dominated by carbonate rocks and shales, which form the source rocks of the area. Most of these are mature, though some of the younger units are immature. All of the Pennsylvanian shales and some of the limestones are considered source rocks. Other known source rocks are the Mississippian Chattanooga Shale, and the Ordovician Simpson Sandstone and Maquoketa Shale.

P-400, CENTRAL KANSAS UPLIFT, SALINA BASIN, NEMAHA ANTICLINE AND SEDGWICK BASIN

Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Mesozoic		
Late Cretaceous	Pierre Shale	shale
	*Niobrara Formation	chalk, limestone
	#Carlile Shale	shale, siltstone, sandstone
	Greenhorn Limestone	limestone, shale
	Graneros Shale	shale
	#Dakota Formation	sandstone, shale
Paleozoic		
Permian	Nippewalla Group	shale, sandstone
	Sumner Group	shale
	*Chase Group	limestone, shale
	*Council Grove Group	limestone, shale
	*Admire Group	limestone, shale
Pennsylvanian	*Wabaunsee Group	limestone, shale
	*Shawnee Group	limestone
	*Douglas Group	shale, sandstone, limestone
	*Lansing Group	limestone, shale
	*Kansas City Group	limestone, shale
	*Pleasanton Group	limestone, shale
	*Marmaton Group	limestone, shale
	*Cherokee Group	shale, limestone
	*Atoka Formation	shale
Mississippian	*Ste. Genevieve Limestone	limestone
	*St. Louis Limestone	limestone
	*Salem (Spergen) Limestone	limestone
	*Warsaw Limestone	limestone
	*Keokuk-Burlington Limestone	limestone
	Chauteau Group	
	Hannibal Shale	shale
	Gilmore City Limestone	limestone
	#Hampton Group	limestone
	Boice Shale	shale
	North Hill Group	limestone
Devonian	Grassy Creek Formation-#"Chattanooga" Shale	shale
	Callaway Formation-Cedar Valley Formation	limestone
Silurian		
Ordovician	Maquoketa Formation	
	Kimmswick Formation	limestone
	Decorah Formation	limestone, shale
	Plattin Formation	limestone
	Platteville Formation	
	Joachim Dolomite	dolomite
	*St. Peter Sandstone	sandstone
	*Arbuckle Group	limestone
Cambrian	*Lamotte Sandstone	sandstone

* Currently producing # Potentially prodcutive

P-410, ARKOMA BASIN

This province covers southeastern Oklahoma, western and central Arkansas. It is primarily a gas-producing province. The Oklahoma portion of the province was formerly known as the McAlester coal basin. The Arkoma basin is bounded on the north by the Ozark uplift, on the northwest by the Central Oklahoma platform and Seminole arch, on the west by the Arbuckle Mountains, on the south by the Ouachita Mountains, and on the east by the Mississippi Embayment. It is a Paleozoic basin containing more than 19,000 feet of Pennsylvanian and older rocks.

Most of this province has been explored, but there are some areas which are more complex structurally and which have not yet been explored extensively. These areas lie in the southern portion of the province. The southeastern portion of Oklahoma has not seen any major exploration to date and the area is largely untested.

Reservoir rocks. Most of the reservoirs are Pennsylvanian. Lenticular sandstones of the Atokan Series are the major producers. Both sandstones and limestones of the Morrowan Series form reservoirs in the region. Mississippian carbonate rocks and sandstones produce both oil and gas. Older units (Ordovician-Silurian) produce oil and gas from sandstone and carbonate reservoirs. Some reservoirs are as shallow as 400 feet.

Traps. Anticlines and faulted anticlines form traps for all intervals. Anticlines in the province are generally large; some are up to 40 miles long and 12 miles wide with up to 3,000 feet of closure. Facies changes associated with channel sands and deltaic complexes are the dominant traps in Des Moinesian and Atokan rocks.

Potential source rocks. All stratigraphic intervals (Ordovician-Pennsylvanian) provide mature source rocks for the province. Most of these are marine shales, but limestones are sources for some reservoirs.

P-420, ANADARKO BASIN, PALO DURO BASIN, AMARILLO ARCH AND CHATAUQUA PLATFORM

This is one of the major gas-producing provinces of the United States. Much of the gas is non-associated, but large quantities of oil and associated/dissolved gas are also produced. Non-associated gas is the main product in the western portion. Oil and associated/dissolved gas are the major constituents in the central and eastern portions of the region. There is very little production in the Palo Duro basin or Wichita Mountains, but the Palo Duro basin has potential for future discoveries.

The Anadarko basin is a northwest-southeast-trending depositional and structural basin. It is bounded on the north by the Cambridge arch-Central Kansas uplift, on the northeast by the Nemaha uplift, on the east by the Arbuckle Mountains, on the south by the Wichita Mountains and Amarillo uplift, on the west by the Cimarron uplift, and on the northwest by the Las Animas arch. The Anadarko basin is highly asymmetrical with the steep side next to the Wichita Mountains. The northwestern end of the basin is called the Hugoton Embayment. The Hugoton-Panhandle field complex covers all or parts of 19 counties in Texas, Oklahoma, Kansas, and Colorado. The deeper portion of the Anadarko basin may contain over 40,000 feet of sedimentary rocks. In the Hugoton area, there are over 2,000 feet.

All rocks which overlie the Ordovician in the shallower portions of the Anadarko basin are considered to be mature exploration targets and it is expected that future new field discoveries would occur in comparatively small stratigraphic traps. Ordovician exploration at depths of 10,000 to 15,000 feet is relatively immature overall; most large structures have been drilled, but many smaller structures are untested. It is expected that Ordovician rocks at depths of 10,000 to 15,000 feet may yield small- and intermediate-sized fields in the future. The rocks below 15,000 feet in the Anadarko basin are still relatively unexplored, except for localized trends which occur just below 15,000 feet and which have reached mature stages of development. Both the Pennsylvanian clastic rocks and the older pre-Pennsylvanian carbonate rocks below 15,000 feet in

P-420, ANADARKO BASIN, PALO DURO BASIN, AMARILLO ARCH AND CHATAUQUA PLATFORM

Generalized Stratigraphic Section

AGE	TX-OK PANHANDLES	CENT.-W. OKLA.	SO. OKLA.
Mesozoic			
Cretaceous			
Late			Eagle Ford Shale
	Greenhorn Limestone		
	Graneros Shale		*Woodbine Sandstone
	Dakota Sandstone		
Early	Kiowa Shale		*Washita Gp.-ls., ss.
	Cheyenne Sandstone		Fredricksburg Gp.-ls.
			Trinity Gp.
Jurassic	Morrison Fm.-sh.		
Triassic	Dockum Fm.-ss.		
Paleozoic			
Permian	Quartermaster Fm.-ss.		
	Cloud Chief Fm.		
	Whitehorse Gp.-dol.		
	Blaine Fm.-ls.		
	Glorieta Sandstone		El Reno Gp.-ss., sh.
	*Clear Fork Gp.-ls., ahy.		Hennessey Shale
	Wichita Fm.-ls.		Wellington Fm.-sh.
	Brown Dolomite		#Chase Group-ls., sh.
			*Council Gr. Gp.-ls.sh.
			Admire Gp.-ls. sh.
Pennsylvanian	*Wabaunsee Gp.-ss.		
	*Shawnee Gp.-ss.		*Cisco Gp.-ls., ss.
	*Douglas Gp.-ss.		
	*Lansing Gp.-ss., ls.	#Ochelata Gp.-sh.	
	*Kansas City Gp.-ls., ss.	#Skiatook Gp.-sh.	*Hoxbar Gp.-ss.
	*Pleasanton Gp.-ls., ss.		
	*Marmaton Gp.-ss., ls.	*Big Lime-ls.	*Deese Gp.-ss., cgl.
	*Cherokee Gp.-ss.	*Oswego-ls.	
	*Thirteen Finger Ls.		*Upper Dornick Hills-ss.
	*Morrow Fm.-sh., ss.	*Morrow Fm.-sh., ss.	*Morrow Fm.-sh., ss.
Mississippian	*Springer Sandstone	#Caney Sh.-sh.	
	*Goddard Shale	*Chester Ls.-ls.	
	#Caney Fm.-sh.	*Warsaw Ls.	
		Keokuk- Burlington Ls.	
		Fern Glen Ls.	
	Welden Fm.-ls.	Sedalia Fm.-ls.	
		Chauteau Ls.	
	Woodford Shale		
Silurian/Devonian	*Hunton Gp.-ls.		
Ordovician	*Sylvan Shale		
	*Viola Ls.-ls.		
	*Simpson Fm.-ss.		
	*Arbuckle Gp.-ls., ss.	*Ellenburger Ls.-ls.	
Cambrian	*Reagan Sandstone		

* Currently producing # Potentially productive

the Anadarko basin may contain undiscovered fields with natural gas accumulations of over 150 billion cubic feet.

Reservoir rocks. Producing formations range in age from Cambrian to Permian. The major reservoirs are mostly upper Paleozoic, including the Permian Leonardian and Wolfcampian Series rocks. Sandstones, conglomerates, limestones, and dolomites are all present in these Series. Wolfcampian carbonates of the Chase, Council Grove, and Admire Groups are the major reservoirs in the Hugoton field. Other important reservoirs in western Oklahoma and the Panhandle region include the Silurian-Devonian Hunton Limestone; the Mississippian "Chester" Limestone and Manning Limestone. In southeastern Anadarko basin, the upper Pennsylvanian Hoxbar Group is very productive. In central Oklahoma, the Atokan, Morrowan, and Springeran Series contain important sandstone and limestone reservoirs. Other productive upper Paleozoic intervals in the region are the Permian Clear Fork Group; the Pennsylvanian Cisco Series, Dornick Group, Deese Group, Marmaton Group including the Oswego Limestone, and Canyon Group (reef limestones and sandstones). Middle Paleozoic reservoirs include the Mississippian Sycamore (Chester) Limestone and the Silurian-Devonian Bois d'Arc Limestone. Lower Paleozoic reservoirs include the Ordovician Sylvan Shale, Viola Limestone, and Simpson Group; the Cambro-Ordovician Arbuckle/Ellenburger Groups; and the Cambrian Reagan Sandstone.

Traps. In most of the province, anticlines and faulted anticlines are important trapping mechanisms for middle and lower Paleozoic rocks. In the Palo Duro basin anticlines affect all productive intervals. Pennsylvanian sandstones consist of channel sandstones, delta complexes and littoral sand packages. Variations of permeability and updip pinchouts of permeability form common traps. In the Arbuckle Group some units have vuggy porosity development within tighter matrix rocks. Unconformities truncate some reservoirs. Evaporites form seals for part of the Amarillo uplift. The potential for hydrodynamic traps is evidenced by tilting of oil/water and gas/oil contacts in some fields.

Potential source rocks. Source rocks are good to excellent in this province. They range from immature to over-mature depending on depth of burial. Probable source rocks include all Pennsylvanian shales and most Mississippian shales and limestones. Another likely source rock is the Devonian-Mississippian Woodford Shale.

P-430, FORT WORTH BASIN, BEND ARCH AND STRAWN BASIN

This province covers the central portion of Texas. It is bounded on the east by the Ouachita tectonic belt and on the south by the Balcones fault zone. It is primarily a Paleozoic province and Paleozoic rocks outcrop at the surface in the northern portion of the province. Lower Cretaceous rocks cover the Paleozoic sediments in the southern portion of the province. The province contains no giant fields. Exploration and development costs are low in the region due to shallow production (depths of 1,300 to 6,000 feet). This makes it an attractive drilling area. Both oil and gas are produced in this province and the gas occurs as both associated/dissolved and non-associated gas.

Reservoir rocks. Reservoir rocks range in age from Cambrian to Permian. Permian reservoirs include both sandstones and limestones of the Wolfcampian and Leonardian series. Limestone, sandstone and conglomeratic rocks form reservoirs in Pennsylvanian age units. Productive Pennsylvanian units include the Cisco, Canyon, Strawn, and Atokan Series. Mississippian reservoirs are limestones of the Barnett and Chappell Formations. Ordovician reservoirs are the Viola, Simpson, and Ellenburger Formations. Production from Cambrian-age rocks is confined to the "granite wash."

Traps. Anticlinal trapping is important in this province. Some anticlines are very large but have low relief; closure may be only tens of feet, but fields may cover many square miles. Some anticlines developed continuously through the deposition of many units and the formation of many unconformities, thus involving many pay zones. Eroded high-relief anticlines form traps for Cambrian and Ordovician units in some areas. Faulted anticlines are a common trapping mechanism in all intervals. Faults are important for some Cambrian oil accumulations. Many unconformities are present in the region and form updip seals for some fields.

Stratigraphic traps include sandstone lenses and pinchouts. Reefs and reefal facies are common. Fracture porosity forms traps in some lower Pennsylvanian carbonates. Combination traps are common.

Potential source rocks. Pennsylvanian and Mississippian units are the most common source rocks and they are all mature. They include the Pennsylvanian Smithwick and Comyn Shales, the Strawn Series, and the Mississippian Barnett Shale. Limestones in the region are possible source rocks.

P-440, PERMIAN BASIN

The Permian basin covers approximately 76,250 square miles and includes 51 counties in west Texas and 4 counties in southeastern New Mexico. All but 6 of these counties are currently productive of oil or gas, and the basin is a major oil and gas (both associated/dissolved and non-associated) province. Lea County, New Mexico is one of the richest oil-producing counties in the country.

The basin is bounded on the east by the Bend arch, on the north by the Amarillo-Ouachita uplift, on the west by the Sacramento Mountains, on the southwest by the Diablo platform, and on the south by the Marathon thrust belt.

Sedimentary rocks within the basin are up to 25,000 feet thick in the deepest parts of the basin. Nearly all of the rocks are of Paleozoic age with a thin veneer of Mesozoic rocks at the surface. Carbonate rocks, both limestones and dolomites, are the dominant lithology. Thick bituminous shales and lenticular sandstones are interspersed with the carbonate rocks. Thick evaporite sequences were deposited during late Permian time.

Reservoir rocks. Reservoir rocks for oil and gas range in age from Cambrian through late Permian. Carbonate rocks form most major reservoirs, although lenticular sandstones produce in parts of the basin. Most production comes from the thick Permian section. Late Permian Guadalupian rocks, the shallowest reservoirs, have produced more than one-half of the oil produced to date in the basin. The Grayburg and San Andres Formations are the most prolific reservoir formations. Other important reservoirs are: Yates Formation, Glorieta Sandstone, Abo Shale, Spraberry Sandstone, Wolfcampian limestones, Cisco Group, Canyon Group, Strawn Group, Siluro-Devonian carbonates and Ellenburger Dolomite. Porosity ranges from vuggy to cavernous in shallower reservoirs to fracture porosity in deeper reservoirs and low permeability, tight, gas sands.

Traps. The major trapping mechanism in the province is anticlinal folds. Most anticlinal fields produce from several stacked reservoirs, some containing as many as 11 pay zones. The anticlines vary in size, but can be up to 16 miles by 6 miles (Eunice-Monument field). Reef and biohermal facies are the second most common trap. These include the Capitan reef (Guadalupian) and the Scurry reef (Pennsylvanian) of the Horseshoe Atoll. The Kelly-Snyder field covers 51,000 acres on the Horseshoe Atoll. The third most common trapping mechanism is the updip pinchout of lenticular sandstone bodies. Fault traps are rare. Some slump blocks form traps. In some parts of the province, buried topographic highs form traps. Seals in the province include evaporites, shales and porosity loss due to facies changes within the carbonates.

Potential source rocks. Bituminous shales were deposited in the basin during Ordovician, Devonian, Mississippian, Pennsylvanian and Permian (Wolfcampian, Leonardian) time. These include the Woodford Shale, Barnett Shale, and Simpson Group. The shales are likely source rocks as are numerous carbonate facies throughout the province. All of the source rocks in the province are mature.

Future exploration. Present exploration is concentrated in the major producing areas. Gas exploration in the deeper portions of the Delaware and Val Verde basins is very promising. The Abo and Capitan reef complexes need further investigation. Additionally, since the majority of fields are contained in the Guadalupian rocks, all of the other known reservoir levels need further examination. The Ellenburger and underlying Cambrian sandstones are good prospective targets. The Precambrian, if highly fractured, could be productive in uplift areas such as the Central Basin platform.

P-440, PERMIAN BASIN
Generalized Stratigraphic Section

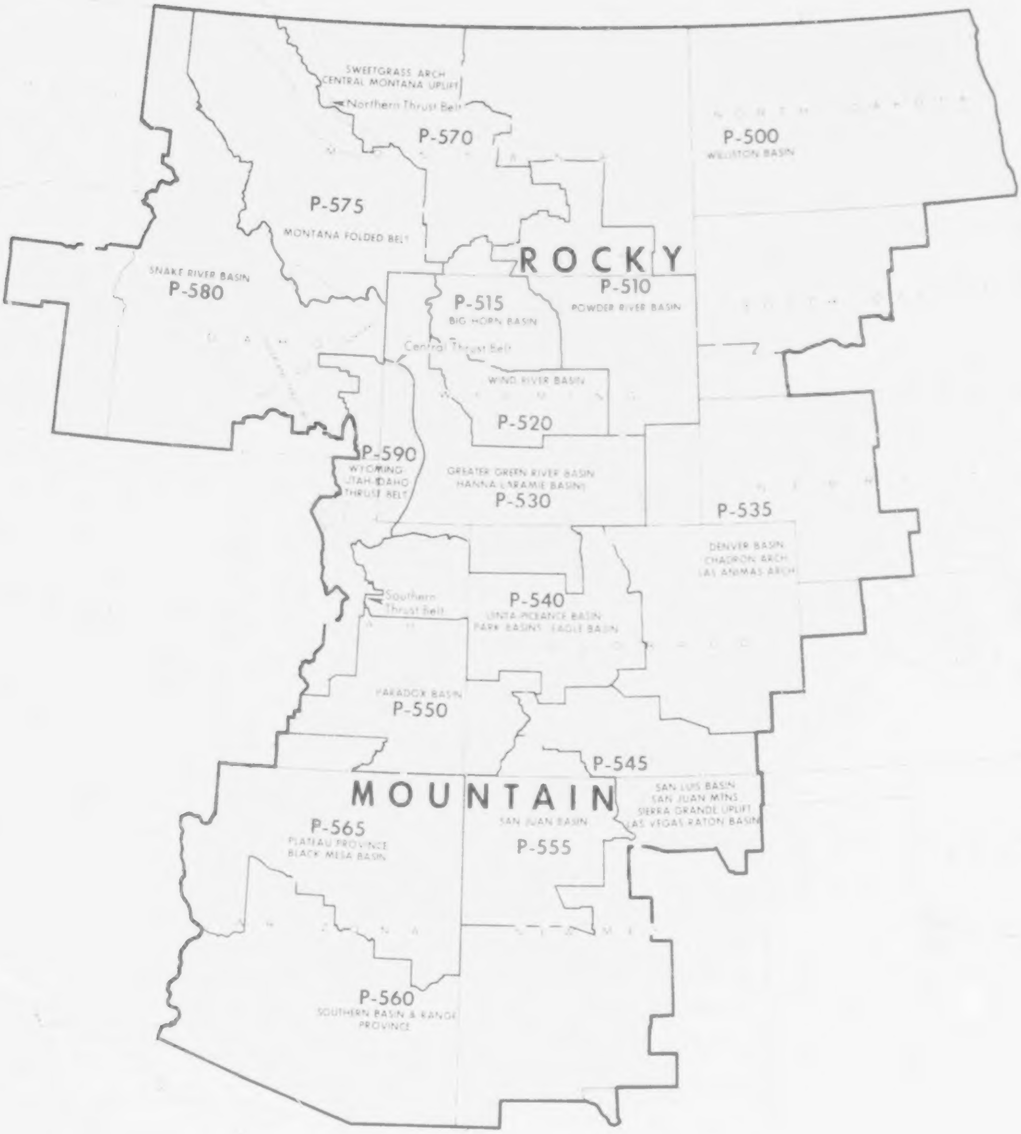
AGE	FORMATION			GENERAL LITHOLOGY
	"Back Reef" Facies	"Reef" Facies	"Basin" Facies	
Mesozoic				
Early Cretaceous		*Edwards Ls.		limestone
			*Comanche Pk. Ls.	limestone
			*Paluxy Ss.	sandstone
	*Trinity Ss.			sandstone
Paleozoic				
Permian	Ochoan Series			evap., sh. , ls.ss.
	Guadalupian Series			
	Tansil Formation)	Capitan Ls.-)		ls. , dol.
	*Yates Formation)	Bell Canyon)		sandstone,
	*Seven Rivers Fm)	Formation)	*Delaware	evaporite
			Mountain	
	*Queen Formation)	Goat Seep Ls.-)	Group	dol.,ss.
	*Grayburg Fm.)	Cherry Canyon Fm.)		
	*San Andres Fm.)			
	*Glorieta Sandstone	#Brushy Canyon Fm.		sandstone
	Leonardian Series			
	*Clear Fork Grp.	*Yeso Dolo.	*Spraberry Ss.	carbonate,
				siltstone
	*Abo Shale			shale
	*Wolfcamp Group	Hueco Ls.		ls., shale
Pennsylvanian	*Cisco Group--Virgil Group)		*Scurry	sh.,ls.
	*Canyon Group--Missouri Grp.)		Reef	sh., ls.
	*Strawn Grp.--Des Moines Grp.)		Ls.	limestone
	*Atoka Group--Bend Group			ls., shale
	*Morrow Group			sandstone
Mississippian	Barnett Shale--"Helms fm."			shale
	#Rancheria Fm.--"Mississippian ls."			limestone
	Kinderhook Formation			limestone
Devonian	Woodford Shale			shale
	Thirtyone Formation			limestone
Silurian	*"Silurian ls."--Wristen Fm.			ls., shale
	*Fusselman Dolomite			dol., ls.
Ordovician	Sylvan Shale			shale
	Montoya Dolomite			dol.,ls.
	Simpson Group			ls., sh.,ss.
	*Ellenburger Dolomite			dolomite
Cambrian	#Bliss Sandstone			sandstone
Precambrian				

* Currently producing # Potentially productive

Table 14. Estimated resources of natural gas for provinces of the Mid-Continent Area, December, 1986 (billion cubic feet)

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPECULATIVE		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-400, Central Kansas	0-15,000'		600	400	300	200	100	100	*	*	*
uplift, Salina basin, etc.	15-30,000'								*	*	*
P-410, Arkoma basin	0-15,000'		4,300	3,700	2,400	2,400	2,100	1,300	3,100	2,600	1,700
	15-30,000'								*	*	*
P-420, Anadarko basin,	0-15,000'		29,300	18,100	10,300	29,400	16,400	7,400	42,400	23,500	10,300
Palo Duro basin, etc.	15-30,000'		15,000	9,400	7,500	47,000	37,600	28,200	92,300	34,200	12,700
P-430, Ft. Worth basin,	0-15,000'		3,000	2,300	1,500	2,500	2,000	900	1,000	800	100
Bend arch, Strawn basin	15-30,000'								*	*	*
P-440, Permian basin	0-15,000'		10,200	6,200	3,400	29,400	18,900	4,500	1,700	1,000	100
	15-30,000'		12,600	7,500	4,200	19,500	13,700	6,000	*	*	*
TOTAL, onshore	0-15,000'			30,700			39,500			27,900	
TOTAL, onshore	15-30,000'			16,900			51,300			34,200	
TOTAL, onshore, all depths				47,600			90,800			62,100	
GRAND TOTAL FOR AREA				47,600			90,800			62,100	

*Negligible quantity of natural gas estimated


SWEETGRASS ARCH
CENTRAL MONTANA UPLIFT
Northern Thrust Belt
P-570
NORTH DAKOTA
P-500
WILLISTON BASIN
P-575
MONTANA FOLDED BELT
ROCKY
SNAKE RIVER BASIN
P-580
P-515
BIG HORN BASIN
P-510
POWDER RIVER BASIN
Central Thrust Belt
WIND RIVER BASIN
WYOMING
P-520
P-590
WYOMING-
UTAH-IDAHO
THRUST BELT
GREATER GREEN RIVER BASIN
HANNA LARAMIE BASINS
P-530
P-535
DENVER BASIN
CHADRON ARCH
LAS ANIMAS ARCH
Southern
Thrust Belt
P-540
UINTA-PICEANCE BASIN
PARK BASINS EAGLE BASIN
PARADOX BASIN
P-550
P-545
MOUNTAIN
SAN LUIS BASIN
SAN JUAN MTNS
SIERRA GRANDE UPLIFT
LAS VEGAS-RATON BASIN
P-565
PLATEAU PROVINCE
BLACK MESA BASIN
SAN JUAN BASIN
P-555
P-560
SOUTHERN BASIN & RANGE
PROVINCE

ROCKY MOUNTAIN AREA

The greatest potential for non-associated natural gas in the Rocky Mountain Area is concentrated in southwestern Wyoming and adjacent northwestern Colorado and northeastern Utah. This region includes the Greater Green River basin, the Uinta-Piceance basins and, to a lesser extent, the Wind River basin. All of these basins have a Tertiary and Cretaceous section containing large volumes of carbonaceous and coaly sediments in addition to marine sediments. Below a depth which generally corresponds to the 200° F isotherm, the sediments tend to be over-pressured because gas is being generated and cannot escape from the low permeability sediments. The primary criterion for locating commercial gas production is finding a reservoir which is porous, permeable and continuous. Much of the gas which has been and will be found is in reservoirs which are classified as "tight." The western Green River basin also includes the multi-trillion-cubic foot accumulation of gas with low hydrocarbon content, and hence low Btu value, found in Paleozoic sediments on the Moxa arch. This accumulation extends into the Wyoming-Utah-Idaho Thrust Belt province beneath the thrusting.

The second province with major natural gas potential in the Rocky Mountain Area is the Wyoming-Utah-Idaho Thrust Belt. Large accumulations have been found in the Fossil basin area located in the southwestern corner of Wyoming and adjacent northern portions of Utah. The fields are primarily on the hanging wall of the Absaroka Thrust where early Mesozoic and Paleozoic reservoirs involved in complexly faulted anticlines have been thrust eastward over Cretaceous source sediments. The Mesozoic reservoirs tend to contain sweet gas and condensate, whereas the Paleozoic reservoirs tend to contain sour gas and condensate. Reservoir sediments have been thrust over Cretaceous sediments in other portions of this province. However, there has been sufficient exploratory drilling to show that numerous major accumulations comparable to those in the Fossil basin are not likely to exist throughout the trend. The potential for gas derived from other possible source sediments and for production from Cretaceous sediments is still uncertain.

The Montana Folded Belt may contain accumulations resulting from geologic relationships which are grossly comparable to those existing, and postulated to exist, in the Wyoming-Utah-Idaho Thrust Belt. The Sweetgrass arch and Central Montana Uplift province contains numerous accumulations of associated and non-associated gas in a wide variety of structural and stratigraphic traps involving Paleozoic and Mesozoic reservoirs. The geologic variations found within this province provide opportunity for additional potential gas resources.

The Williston basin is primarily an oil province with most gas reserves and resources in the associated/dissolved category. Deeper accumulations within the basin tend to have higher gas/liquid ratios.

The Powder River basin of eastern Wyoming and Montana is also primarily an oil-producing region from Permo-Pennsylvanian and Cretaceous reservoirs. However, discoveries in the Amos/Andy area of Campbell County, Wyoming, are gas-condensate accumulations. Six fields, including Hilight, Kitty and Lance Creek, have produced in excess of 50 Bcf of associated gas. The Big Horn basin of Wyoming and Montana has potential for significant gas accumulations, primarily in Cretaceous sediments in the central, deeper portions of the basin, even though current production is primarily oil from Paleozoic reservoirs around the margins of the basin.

Most of the gas in the Denver basin is contained in one major non-associated accumulation in the Wattenberg area north of Denver. This accumulation is in the Lower Cretaceous "J" sand and is essentially in a stratigraphic trap on a "paleo high." The areal extent of the field is expected to expand with further development. The development of additional gas resources is anticipated in the Upper Cretaceous Hygiene, Niobrara and Codell-Timpas intervals, plus additional associated gas with the "D" and "J" sand oil accumulations. Speculative resources are projected in younger Upper Cretaceous formations and in Paleozoic sediments.

The overlapping, multi-pay accumulations of gas in Upper Cretaceous sandstones which characterize the San Juan basin constitute the largest known gas reserve in the Rocky Mountain Area. Potential resources, estimated to be trillions of cubic feet, have been assigned to this basin.

Additional accumulations, comparable to those which have been found previously, are expected in the Paradox basin. Gas/liquid ratios are expected to be higher in the deeper parts of the basin. The Snake River basin, Black Mesa basin and the Southern Basin and Range province are assigned only minor gas potential based on present information.

Estimates of potential resources for the Rocky Mountain Area are approximately 14% lower for the total of all resource categories than the corresponding total at the end of 1984. The change results primarily from changes in estimates for three provinces. The most likely estimates for the Unita and Piceance basins (province P-540) have been reduced approximately 30% based on a very detailed analysis of future potential based on well performance. The most likely estimates for the Wyoming-Utah-Idaho Thrust Belt (province P-590) have been reduced about 26% based on two facts: (1) recent drilling, plus seismic data, indicate little room for additional major accumulations in the Fossil basin and immediate vicinity; and (2) drilling and seismic data show that the prolific reservoirs which are located in the Mesozoic and upper Paleozoic rocks of the Fossil basin are not present in the hanging wall of the thrust fault north of the Fossil basin--the only remaining objectives are in the Madison Limestone (Mississippian) and older rocks. A detailed study of the Greater Green River basin (province P-530) has resulted in increasing the most likely estimates for all categories of resources in the shallow depths of the basin, as well as the most likely estimate of Possible resources in the deeper potion of the basin, and in decreasing the most likely estimates for deep Probable and Speculative resources.

P-500, WILLISTON BASIN

This sedimentary basin covers more than 225,000 square miles in North Dakota, South Dakota, eastern Montana, southern Saskatchewan and southwestern Manitoba. It is bounded on the east by the Canadian Shield, on the southeast by the Sioux uplift, on the southwest by the Black Hills uplift and on the west by the Big Snowy uplift. Production occurs in all three states and both Canadian provinces. More than 16,000 feet of sediments lie in the deepest portion of the basin, and, of these, 5,000 to 7,000 feet are Paleozoic sediments, mostly carbonates and evaporites, and 6,000 feet are Mesozoic rocks, primarily clastics.

Gas production in this basin is primarily associated with oil. Exceptions to this are found in a handful of wells in the Ordovician and Cambro-Ordovician on and near the Nesson anticline and in the Cretaceous on the Cedar Creek anticline.

The Probable resources are expected to be mostly associated gas, found within the boundaries of existing fields through field extensions. The Possible resources are expected to be mostly associated gas. Field size probably will be extremely variable, with most in the 1 to 3 Bcf range. The Speculative resources are expected to be primarily non-associated gas found in fields from 3 to 100 Bcf.

Reservoir rocks. Production occurs in reservoir formations ranging in age from Cambrian to Cretaceous. These productive units are the Cretaceous Colorado Group and Montana Group; the Permian-Triassic Spearfish Formation; the Pennsylvanian Tyler Formation; the Mississippian Big Snowy Group and Madison Group; the Devonian-Mississippian Bakken Formation; Devonian carbonate rocks; the Silurian Interlake Formation; the Ordovician Stony Mountain, Red River and Winnipeg Formations; and the Cambrian Deadwood Formation. Cretaceous Dakota Group sandstones, as well as sandstones in the Jurassic Swift Formation, are potential reservoirs for natural gas.

Traps. Anticlines and faulted anticlines provide traps for all potential reservoirs. Stratigraphic trapping is also very important. Principal types of stratigraphic traps are porosity variations and truncations updip into impermeable units, such as

P-500, WILLISTON BASIN
Generalized Stratigraphic Section

AGE	FORMATION		GENERAL LITHOLOGY
	West	East	
Cenozoic			
Paleocene	Sentinel Butte Formation		shale, sandstone, coal
	Fort Union Formation		sandstone, shale, coal
Mesozoic			
Late Cretaceous	Hell Creek Formation		shale, sandstone
	Montana Group		
	Fox Hills Formation		sandstone
	Bearpaw Shale	*Pierre Shale	shale
	Judith River Fm.		sandstone
	Claggett Formation		shale
	*Eagle Formation		sandstone
	Telegraph Creek Formation		sandstone
	Colorado Group		
	#Niobrara Formation		shale, marl, limestone
	#Carlile Formation		shale
	#Greenhorn Formation		shale, marl, limestone
	#Belle Fourche Formation		shale
Early Cretaceous	#Mowry Shale		shale
	Dakota Group		
	#Muddy Sandstone	#Newcastle Ss.	sandstone
	#Skull Creek Fm.	#Skull Crk Fm	shale
	#Dakota.Fm.	#Inyan Kara Fm.	sandstone
	#Kootenai Fm		sandstone
	#Lakota Fm.		sandstone
Jurassic	Morrison Formation		shale
	Ellis Group		
	#Swift Fm.	#Swift Fm.	shale, ss., ls.
	Rierdon Fm.	Rierdon Fm.	shale, limestone
	#Piper Fm.	#Piper Fm.	shale, ls., ss.
	Nesson Fm.		shale
		Dunham Salt	evaporites
Paleozoic			
Permian-Triassic	*Spearfish Fm.		shale, sandstone
	Pine Salt		evaporites
Permian	Minnekahta Fm.		limestone
	Opeche Fm.		shale, evaporites
Penn. - Permian	Minnelusa Formation		sandstone, dolomite, shale
Pennsylvanian	Amsden Formation		dolomite, shale
	*Tyler Formation		shale, sandstone
Mississippian	Big Snowy Group		
	Heath Formation		shale, sandstone
	Otter Formation		shale
	#Kibbey Formation		sandstone, limestone
	Madison Group		
	*Charles Formation.		evaporites, limestone
	*Mission Canyon Fm.		limestone, shale
	#Lodgepole Formation		limestone, shale

*Currently producing   #Potentially productive

P-500, WILLISTON BASIN
Generalized Stratigraphic Section (continued)

AGE	FORMATION West	 East	GENERAL LITHOLOGY
Devonian-Miss.		*Bakken Formation	shale
Devonian		*Three Forks Formation	shale, evaporites
	*Birdbear ("Nisku") Fm.		limestone
		*Duperow Fm.	dolomite, limestone
		#Souris River Formation	limestone
		#Dawson Bay Fm.	limestone
		Prairie Fm.	evaporites
		*Winnipegosis Fm.	limestone
		Ashern Fm.	dolomite
Silurian		*Interlake Formation	dolomite, limestone
Ord.-Silurian		*Stonewall Formation	dolomite, limestone
Ordovician		*Stony Mountain Formation	limestone, dolomite
		*Red River Formation	limestone, dolomite, evap.
		*Winnipeg Formation	sandstone, shale
Cambro-Ordovician		*Deadwood Formation	sandstone, shale

* Currently producing # Potentially productive

evaporites. Next in importance are sandstone lenses and channels, found dominantly in the Big Snowy, Tyler and Lower Cretaceous units. Reefs, bioherms and buried topography form traps in the Red River, Interlake, Madison, and Devonian carbonate rocks. Combinations of these traps exist. Hydrodynamic trapping occurs in some anticlines.

Potential source rocks. Hydrocarbons in this basin were formed in numerous formations ranging in age from Cambrian to Paleocene. These formations include the Bakken, Red River, Winnipeg and Deadwood Formations, as well as the Paleocene Fort Union Formation; Upper Cretaceous Niobrara Formation; Lower Cretaceous Mowry Formation; Pennsylvanian Tyler Formation; Mississippian Heath and Lodgepole Formations; and Devonian Birdbear (Nisku) Formation.

Producing trends. The most noticeable structural feature in the province is the Cedar Creek anticline of southeastern Montana. This northwest-southeast-trending structure is over 100 miles long and contains up to 440 feet of productive section in lower Paleozoic carbonate rocks. Other major anticlines are the Bowdoin dome and Nesson and Billings anticlines.

P-510, POWDER RIVER BASIN

The Powder River basin is bounded on the east by the Black Hills, on the southeast by the Hartville uplift, on the south by the northwest end of the Laramie Range, on the west by the Casper arch and Big Horn Mountains, and on the north by the Miles City arch. This asymmetrical structural basin covers over 20,000 square miles. It is primarily an oil-producing basin, and natural gas represents a relatively minor portion of the basin's petroleum resources.

Primarily, gas found in all categories in the Powder River basin will be associated. Very probably, the only non-associated gas will be shallow coalbed methane. The Probable resources will come from field extensions, step-outs, etc., primarily in the deeper region of the basin. The Possible resources are expected to occur in field-sizes of 5 to 300 Bcf and generally limited to the lower end of the range. Speculative resources may be found in the deeper synclinal area of the basin at 15,000 feet and greater in depth. Sizes may range from 20 to 200 Bcf.

Reservoir rocks. Potential reservoir rocks vary in age from Pennsylvanian to Cretaceous. Formations which are currently productive include the

P-510, POWDER RIVER BASIN
Generalized Stratigraphic Section

AGE	FORMATION		GENERAL LITHOLOGY
	West	East	
Cenozoic			
Oligocene	White River Formation		shale, conglomerate
Eocene	Wasatch Formation		conglomerate, sandstone, shale
Paleocene	*Fort Union Formation		sandstone, shale, conglomerate
Mesozoic			
Cretaceous			
Late	*Lance Formation		sandstone, shale
	*Fox Hills Formation		sandstone
	Mesaverde Formation	Pierre Shale	shale, sandstone
	*Lewis Shale Member		shale
	*Teapot Sandstone Member		sandstone
	*Parkman Shale Member		shale, sandstone
	Cody Shale	Steele Fm.	shale, sandstone
	*Shannon Sandstone Member		sandstone
	*"Ash Creek" Sandstone		sandstone
	*Niobrara Formation		shale, marl, limestone
	Carlile Shale		shale
	Greenhorn Formation		shale, limestone
	*Frontier Fm.	Bell Fourche Sh.	shale, sandstone
Early	*Mowry Shale		shale
	*Muddy Ss.	*Newcastle Ss.	sandstone, shale
	Thermopolis Sh.	Skull Creek Sh.	shale
	Inyan Kara Group		shale,sandstone
		*Fall River Fm.	shale, sandstone
		*Lakota Fm.	sandstone
Jurassic	Morrison Formation		shale, sandstone
	*Sundance Formation		sandstone, shale
	Gypsum Springs Formation		anhydrite, limestone, shale
Triassic	Chugwater Group–Spearfish Fm.		sandstone, shale, siltstone
Paleozoic			
Permian	Goose Egg Fm.–Minnekahta Ls.		shale, anhydrite, limestone
Permian-Penn.	*Tensleep Sandstone	*Minnelusa Fm.	sandstone, shale, dolomite
Pennsylvanian	*Amsden Formation		limestone, sandstone
Mississippian	#Madison Ls.–Pahasapa Ls.		limestone
Devonian	Jefferson Formation		limestone
Ordovician	#Bighorn Dolo.	Whitewood Dolo.	dolomite
Cambrian	Gallatin Limestone		limestone
	Gros Ventre Fm.	#Deadwood Fm.	shale, limestone, sandstone
	Flathead Sandstone		sandstone

* Currently producing # Potentially productive

Upper Cretaceous Fox Hills Formation, Teapot Formation, Parkman Sandstone, Sussex Sandstone, Shannon Sandstone, Ash Creek Formation and Frontier Sandstone; the Lower Cretaceous Muddy-Dakota-Newcastle Formations, and Inyan Kara Group (Lakota Formation); the Jurassic Sundance Formation; and the Pennsylvanian Minnelusa-Tensleep Formations.

Traps. Anticlinal traps are common in the western portion of the basin. The central portion has buried topographic traps. The eastern portion is dominated by traps created by variations in the permeability of the reservoir rocks. Lenticular sandstones are found throughout the basin.

Potential source rocks. Organic-rich sediments were deposited at various times during the history of the region. Potential source rocks range in age from Pennsylvanian to Paleocene. They include the Paleocene Fort Union Formation; the Upper Cretaceous Lance, Lewis, Steele, Niobrara, Frontier and Greenhorn Formations; the Lower Cretaceous Mowry and Skull Creek Shales; the Jurassic Sundance Formation; the Permian Phosphoria Formation; and the Pennsylvanian Minnelusa Formation.

Potential for future exploration. The basin has good potential since large areas have not been explored. In explored areas, many potential reservoir rocks remain relatively untested. Many undiscovered stratigraphic traps are believed to exist.

P-515, BIG HORN BASIN

This province covers approximately 11,000 square miles in northern Wyoming and southern Montana. It is primarily an oil province and most gas occurs as associated/dissolved gas although non-associated gas is produced from Cretaceous formations as well as the Paleocene Fort Union Formation. The basin is bounded on the west by the Absaroka Range and the Beartooth Mountains, on the south by the Owl Creek Mountains, on the east by the Big Horn Mountains and on the north by the Nye-Bowler lineament. The basin is covered by Tertiary continental sedimentary rocks which are as much as 8,000 feet thick. Mesozoic sedimentary rocks are up to 9,800 feet thick. The Paleozoic section is only approximately 2,300 feet thick.

Reservoir rocks. Potential reservoir rocks range in age from Cambrian to Paleocene. The most prolific reservoirs are the Permian Phosphoria Formation (Embar Limestone Member) and the Pennsylvanian Tensleep Formation. Other reservoir formations are the Paleocene Fort Union Formation; the Upper Cretaceous Lance Formation, Mesaverde Formation and Frontier Sandstone; the Lower Cretaceous Muddy, Dakota, Lakota and Fuson Formations; the Triassic Chugwater and Curtis Formations; the Pennsylvanian Amsden Formation (Darwin Sandstone Member); the Mississippian Madison Limestone; the Devonian Darby Formation; the Ordovician Big Horn Dolomite; and the Cambrian Flathead Sandstone.

Traps. The major traps are anticlines and faulted anticlines, often combined with changes in porosity and permeability of reservoir formations. Many reservoirs demonstrate tilted oil/water or gas/water contacts due to hydrodynamic flow of water through the permeable formations. Channel and lenticular sandstones occur as well as facies changes in the carbonate reservoir rocks.

Potential source rocks. Potential source rocks occur at several stratigraphic levels, including the Paleocene Fort Union Formation; the Upper Cretaceous Lance, Mesaverde, Cody, Niobrara and Frontier Formations; the Lower Cretaceous Mowry and Thermopolis Shales; the Permian Phosphoria Formation; and in Upper Devonian rocks.

Future exploration. To the present time exploration has concentrated on anticlinal structures in the basin and the main target formations have been the Pennsylvanian-Permian units. Future targets include possible stratigraphic traps and the thick Mesozoic section, especially the various sandstones within the Mesaverde, Frontier and Dakota Formations.

P-515, BIG HORN BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Oligocene	Wiggins-White River Formations	conglomerate, shale, sandstone
Eocene	Pitchfork Formation	sandstone
Paleocene-Eocene	Wasatch Formation	shale, sandstone, conglomerate
Paleocene	*Fort Union-Polecat Bench Formations	shale, sandstone
Mesozoic		
Cretaceous		
Late	*Lance Formation	shale, sandstone
	*Meeteetse Formation	sandstone
	Mesaverde Formation	sandstone, shale
	Cody Shale	shale, sandstone, limestone
	Niobrara Member	limestone
	*Frontier Formation	shale, sandstone, limestone
Early	Mowry Shale	shale
	Shell Creek Shale	shale
	*Muddy-Dakota Sandstones	sandstone
	Thermopolis Shale	shale, sandstone
	*Cloverly-Lakota- Fuson Formations	sandstone, shale
Jurassic	Morrison Formation	shale, sandstone
	*Sundance Fm.-Ellis Group	sandstone, shale, limestone
	Gypsum Springs Formation	limestone, shale
Triassic	Chugwater Grou	sandstone,shale
	Crow Mountain Sandstone	sandstone
	Dinwoody Formation	shale, limestone
Paleozoic		
Permian	*Phosporia-Park City Formations	shale, chert, limestone, sandstone
Pennsylvanian	*Tensleep Sandstone	sandstone
	*Amsden Formation	limestone, sandstone
	*Darwin Sandstone Member	sandstone
Mississippian	*Madison Formation	limestone, dolomite
Devonian	*Three Forks-Jefferson-Darby Fms.	limestone, shale, dolomite
Silurian	Beartooth Butte Formation	shale, limestone
Ordovician	Leigh/Bighorn Dolomites	dolomite
Cambrian	Gallatin Limestone	limestone
	Gros Ventre Formation	shale, limestone
	*Flathead Sandstone	sandstone

* Currently producing # Potentially productive

P-520, WIND RIVER BASIN

This central Wyoming basin is bounded on the west and southwest by the Wind River Mountains, on the south by the Granite Mountains, on the north by the Owl Creek Mountains and the Washakie Range and on the east by the Casper arch. The basin covers approximately 8,500 square miles. Approximately three-fourths of the basin contains more than 20,000 feet of Paleocene-Eocene sedimentary rocks, and up to 30,000 feet of total sedimentary section occurs in the deeper portions of the basin. The basin was emergent during much of Paleozoic time, thus very little Paleozoic section exists and there is nearly four times as much Mesozoic section as Paleozoic.

Structural features include a series of north-northwest-trending folds along the southern flank of the basin. Along the northern flank, rocks of the Owl Creek Mountains have been thrust southward over younger sedimentary rocks of the basin and on the east the Casper arch is thrust west over sedimentary rocks.

Natural gas in the Wind River basin occurs as both associated/dissolved gas and as nonassociated gas. Most of the gas resource is nonassociated. Many fields produce from multiple reservoirs. A multibillion cubic foot accumulation in the Mississippian Madison Limestone has been discovered by a well on the Madden anticline below 20,000 feet.

Reservoir rocks. The major developed reservoir formation in the basin is the Pennsylvanian Tensleep Formation, but additional formations produce gas and/or oil in the basin, including the Tertiary Wind River and Fort Union Formations; the Upper Cretaceous Lance, Mesaverde, Cody and Frontier Formations; the Lower Cretaceous Muddy, Dakota, Cloverly-Lakota Formations; the Jurassic Morrison and Sundance-"Curtis" Formations; the Triassic Nugget and Crow Mountain Formations; the Permian Phosphoria Formation (Embar Limestone Member) and the Mississippian Madison limestone. Many of the Tertiary and Upper Cretaceous reservoirs fall in the "tight" classification.

Traps. Anticlines and faulted anticlines form traps in all stratigraphic intervals. Sandstone channels and lenses are common. Porosity and permeability changes and pinchouts are also abundant in all intervals.

Potential source rocks. Potential source rocks range in age from Permian to Tertiary. They include the Tertiary Fort Union-Waltman Formations; the Upper Cretaceous Lance, Mesaverde, Cody, Niobrara and Frontier Formations; the Lower Cretaceous Mowry and Thermopolis Shales; and the Permian Phosphoria Formation.

Future exploration. The Wind River basin is in an intermediate stage of exploration. Potential targets exist in stratigraphic traps and in untested intervals within all parts of the stratigraphic section. Undiscovered traps and potential reservoirs are believed to exist along the northern and eastern flanks of the basin in sedimentary rocks beneath thrust faults.

P-530, GREATER GREEN RIVER BASIN, HANNA AND LARAMIE BASINS

The Greater Green River basin extends over parts of southwestern Wyoming, northeastern Utah and northwestern Colorado. The province includes several smaller basins in addition to the Green River basin proper: Red Desert basin, Washakie basin, Sand Wash basin, Hanna basin, Kundt basin, Shirley basin and Laramie basin. Approximately 27,000 square miles of prospective sedimentary basins are included in this province which is bounded on the west by the Utah-Wyoming-Idaho Thrust Belt, on the north by the Wind River and Granite Mountains, on the east by the Laramie Range and on the south by the Unita Mountains and the Axial Basin anticline. The Green River basin proper contains more than 20,000 feet of Paleocene-Eocene continental sedimentary rocks. The total sedimentary section is over 30,000 feet thick.

Even though tens of thousands of wells have been drilled in the province, large areas are still sparsely tested and vast areas are virtually untested below the shallowest of several prospective stratigraphic horizons. Throughout much of the basin, the Frontier, Dakota and Paleozoic Formations are at an early stage of exploration. Even the lower part of the Mesaverde Group is largely undrilled throughout much of the Green River, Red Desert and Washakie basins.

The Probable resources are expected to be found in field and trend extensions dominated by the

P-520, WIND RIVER BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Oligocene	White River-Wiggins Formations	conglomerate, tuff
Eocene	Wagon Bed Formation	sandstone
	*Wind River Formation	shale, sandstone, conglomerate
	Indian Meadows Formation	shale, sandstone
Paleocene-Eocene	*Fort Union Formation	sandstone, shale
	Waltman Shale Member	shale
Mesozoic		
Cretaceous		
Late	*Lance Formation	sandstone, shale, coal
	#Meeteetse Fm. - Lewis Shale	sandstone, shale, coal
	*Mesaverde Formation	sandstone, shale, coal
	Teapot Sandstone Member	
	Wallace Creek Member	
	Cody Shale	shale
	*Phyles Sandstone Member	
	Niobrara Formation	shale, limestone
	Carlile Formation	shale, sandstone
	*Frontier Formation	sandstone, shale
Early	Mowry Shale	shale
	*Muddy - Dakota Sandstone	sandstone
	Thermopolis Shale	shale
	*"Cloverly" Formation	sandstone, shale
	Lakota Sandstone Member	sandstone
Jurassic	*Morrison Formation	shale, sandstone
	*Sandance - "Curtis" Formation	sandstone, shale
	Gypsum Springs Formation	limestone, dolomite
Jurassic-Triassic	*Nugget Sandstone	sandstone
Triassic	Chugwater Groupshale,	sandstone,limestone
	Popo Agie Formation	shale
	*Crow Mountain Formation	sandstone
	Alcova Limestone	limestone
	Red Peak Formation	shale
	Dinwoody Formation	dolomite, shale
Paleozoic		
Permian	*Phosphoria - Park City - Goose Egg Fms.	limestone, shale, chert
	Ervay - Embar Limestone	limestone
Pennsylvanian	*Tensleep Formation	sandstone
	Amsden Formation	dolomite, sandstone
	#Darwin Sandstone Member	sandstone
Mississippian	*Madison Limestone	limestone
Devonian	Darby Formation	dolomite
	Beartooth Butte Formation	shale, limestone
Ordovician	Bighorn - Leigh Dolomite	dolomite
Cambrian	Gallatin Group	limestone
	Gros Ventre Group	shale, limestone
	Flathead Sandstone	sandstone

* Currently producing # Potentially productive

P-530, GREATER GREEN RIVER BASIN, HANNA AND LARAMIE BASINS

Generalized Stratigraphic Section

AGE	FORMATION			GENERAL LITHOLOGY
	West		East	
Cenozoic				
Miocene	North Park Fm.		Browns Park Fm.	siltstone, sandstone, cong.
Oligocene		#White River Formation		shale, arkose
Eocene	#Bridger Fm.		Washakie Fm.	cong., sandstone, shale
	#Green River Fm.		Wind River Fm.	shale, sandstone, oil shale
Paleocene-Eocene	*Wasatch Fm.		*Hanna Fm.	shale, sandstone
Paleocene	Hogback Fm.	*Ft Union Fm.	#Ferris Fm.	shale, sandstone, coal
Mesozoic				
Late Cretaceous	#Lance Fm.		*Medicine Bow Fm.	sandstone, shale, coal
		#Fox Hills Sandstone		sandstone
		*Lewis Shale		shale, sandstone
		Mesaverde Group		sandstone, shale, coal
		*Almond Formation		sandstone
		*Ericson Formation		sandstone
		*Rock Springs Formation		sandstone
		*Blair Formation		sandstone, shale
	*Hilliard Fm.	*Baxter Sh	*Steele Sh.	shale, sandstone
		*Niobrara Fm.		shale, marl
		Carlile Sh.		shale
		*Frontier Fm.		ss., shale, ls.
		Greenhorn Ls.		limestone
		Belle Fourche Sh.		shale
Early Cretaceous	*Aspen Sh.		*Mowry Sh.	shale, sandstone
	Bear River Fm.			sandstone, shale
		*Muddy Sandstone		sandstone
		Thermopolis Shale		shale
		*"Dakota" Sandstone		sandstone
	Gannett	*"Cloverly" Fm.		sandstone, shale
	Group.		*Lakota Ss. Mbr.	sandstone
Jurassic		*Morrison Formation		shale, sandstone
	Stump Fm.	Curtis Fm.	*Sundance Fm.	sandstone, shale
	Preuss Ss.	Entrada Ss.		sandstone
	Twin Creek	Carmel Fm.		limestone, dolomite
	Ls.	Gypsum Springs Fm.		limestone, dolomite
Triassic		*Nugget Ss.		sandstone
		Ankareh Fm.		sandstone, shale
		Thaynes Ls.		limestone
		Woodside Fm.-Chugwater Gp.		shale, limestone
		Dinwoody Formation		limestone, shale
Paleozoic				
Permian	*Phosphoria Fm.	Park City Fm.	#Goose Egg Fm.	shale, limestone, chert
Pennsylvanian	*Weber Ss.	*Tensleep Ss.	#Casper Fm.	sandstone
Miss.-Penn.	Amsden Fm.	*Morgan Fm.		ls., shale, sandstone
	*Darwin Ss. Mbr.		Round Valley Ls.	limestone, sandstone
Mississippian		*Madison Ls.		limestone
Devonian		Darby Fm.		dolomite
		Leigh Dolo.		dolomite
Ordovician		Bighorn Dolo.		dolomite
Cambrian		Gallatin Ls.		limestone
	Gros Ventre Fm.		Buck Spring Fm.	shale
		*Flathead Ss.		sandstone

* Currently producing # Potentially productive

LaBarge Platform, Moxa Arch and Wamsutter Arch/Washakie basin complexes. Methane from low-Btu gas entrapped in Paleozoic reservoirs of the LaBarge Platform comprises much of the Probable and Possible resources. The Possible resources are expected to be found in fields ranging in size from 2 to 1,000+ Bcf with many of them in the 5 to 50 Bcf range. The Speculative resources are expected to be found in fields ranging in size from 2 to 1,000 Bcf with the most likely size being between 10 to 200 Bcf.

Reservoir rocks. Potential reservoir rocks range in age from Cambrian to Eocene. The major producing formations are sandstones of the Tertiary Wasatch and Fort Union Formations; the Upper Cretaceous Lewis, Mesaverde Group (including the Almond), Frontier Formation; the Lower Cretaceous Dakota Group; the Juro-Triassic Nugget Sandstone and the Mississippian Madison Limestone. Other reservoirs include the Upper Cretaceous Lance-Fox Hills, the Baxter and Steele shales; the Muddy sandstone, the Jurassic Morrison and Sundance, the Permian Phosphoria Formation; the Permo-Pennsylvanian Weber-Tensleep, the Pennsylvanian Amsden and Morgan Formations'and the Cambrian Flathead Sandstone. Many potential reservoir rocks have low permeability.

Traps. Anticlines and faulted anticlines provide traps for reservoirs of all ages. Together with the structural traps, sandstone pinchouts and permeability changes form the major trapping mechanisms. Combination sandstone pinchout-fault traps are productive in some areas.

Potential source rocks. Potential source rocks range in age from Permian to Eocene. They include the Eocene Wasatch and Green River Formations; the Paleocene Fort Union Formation; the Upper Cretaceous Lance, Mesaverde, Lewis, Baxter-Niobrara and Greenhorn Formations; the Lower Cretaceous Mowry-Aspen and Thermopolis Shales; Jurassic shales; and the Permian Phosphoria Formation. Paleocene and Upper Cretaceous coalbeds are major sources of gas and condensate in the deep parts of the basins.

Future exploration. Although the Greater Green River basin is a major natural gas province, it is still lightly explored. Throughout an area of 13,000 square miles, the Cretaceous Frontier and Dakota sandstones have been penetrated in only one percent of the sections. Thrusting of Precambrian rocks over the northern and southern margins of the basins and fractured reservoirs along lineament trends could prove to be of exploration interest. Future exploration will require adequate economic incentives, presently lacking, in order to justify pursuit of subtle stratigraphic traps in deep, low-permeability reservoirs. Exploitation of methane contained in low-Btu gas of the LaBarge Platform/Moxa Arch Paleozoic reservoirs is dependent upon the economics of tertiary recovery of oil using the major component of the gas--carbon dioxide.

P-535, DENVER BASIN, CHADRON ARCH AND LAS ANIMAS ARCH

This province covers over 95,000 square miles and includes three widely different geological features: the Denver basin, the Las Animas arch and the Chadron-Cambridge arches complex. The Denver basin is a north-south asymmetrical sedimentary basin lying in eastern Colorado, southwestern Nebraska and southeastern Wyoming. It is bounded on the southeast by the Las Animas arch, on the northeast and east by the Chadron-Cambridge arches, on the north and northwest by the Hartville uplift, on the west by the Laramie Mountains and the Front Range and on the south by the Apishapa uplift. More than 13,000 feet of sediments, mostly of Cretaceous age, lie in the deepest portion of the basin, below the city of Denver. The sediments thin to less than 6,000 feet on the gently dipping eastern flank of the basin. Both associated and non-associated gas are found in all parts of the basin, while dry gas is limited to the shallow eastern side. This basin also includes the Canon City embayment which contains the second oldest oil field in the United States, discovered in the spring of 1862

The Las Animas arch is a Late Cretaceous-age uplift that extends northeasterly from southeast Colorado through northwest Kansas into south central Nebraska where it terminates in the Cambridge arch which runs perpendicular to the Las Animas arch. Depth to the Precambrian basement is about 6,000 feet along the Las Animas arch and ranges from more than 5,000 feet to zero along the Chadron-Cambridge arches. The latter arches form the northwest

P-535, DENVER BASIN, CHADRON ARCH AND LAS ANIMAS ARCH
Generalized Stratigraphic Section

AGE		FORMATION AND LITHOLOGY	
		North &West	South & East
Cenozoic-	Pliocene	Ogallala Fm.-ss, cong, ls	OgalallaFm- ss,cong,ls,silt
	Miocene	Rosebud Fm.-ss.,silt, sh.	Arikaree Gp.-ss, silt
	Oligocene	Castle Rock Cong./Brule Fm.-cong.,ss.	White River Gp.-ss, cong, sh, silt
	Eocene-Paleocene	#Denver Fm.-Dawson Fm.-ss, sh coal, cong, volc.	
Mesozoic-	Late Cretaceous	Arapahoe Fm.-ss, cong	
		#Laramie Fm./#Lance Fm.-ss.,sh.,coal	
		Fox Hills Ss..-ss	
		#Pierre Sh.-sh, ss	#Pierre Sh.-sh.
		#Richard Ss. Mbr.(Teapot)-ss.	
		*Laramer & Rocky Ridge Ss. Mbrs.(Parkman)-ss.	
		*Terry Ss. Mbr.-ss	
		*Hygiene Ss. Mbr.-ss	
		*Niobrara Fm.- marl, chalk	Niobrara Fm.- marl, chalk
			*"Beecher Is.Zone"-chalk
		*Timpas Ls. Mbr.- chalk	Ft. Hays Ls. Mbr.-chalk
		#Carlile Sh.-sh, ss	Carlile Sh.-sh.,ss.,chalk
		*Codell Ss. Mbr./Turner-Ss. ss.	#Codell Ss.Mbr/ -ss
		*Greenhorn Fm.-sh, ls	
		#Graneros Sh./Bell Fourche Sh.-sh	Bell Fourche Sh.(Graneros)-sh
	Early Cretaceous	*Dakota Gp.-ss, sh	*Dakota Gp.-ss.,sh.
	Jurassic	Morrison Fm.-sh, ss	Morrison Fm.- sh,ss.
		Ralston Creek Fm.-ls.,ss.,sh.,evap.	Ralston Ck.Fm.-ls,ss,sh.evap.
		#Sundance Fm-ss	#Entrada Ss.-ss
		Jelm Fm.-ss.,sh.	
	Triassic	Lykins Fm.(upper)-sh, ls/ Spearfish Fm(upper).-sh	
Paleozoic -	Permian	Lykins Fm.(lower)-ss sh,ls,evap/ Spearfish Fm.(lower)-ss,sh,ls,evap	#Forelle Ls.-ls.
		Minnekahta Ls. -ls	Minnekahta Ls. -ls.
			Blain Gyp.-evap.
		*Lyons Fm. -ss, sh	Lyons Ss./Sumner Gp. -silt,sh.
		Owl Canyon Fm(Satanka Sh.)-sh	Wellington Fm.- ss,silt,sh.
		Ingleside Fm.-ls, sh./*MinnelusaFm.	*Minnelusa Fm.carb,ss,sh./ Chase-Council Gr. Gp ls
			Admire Gp.-ls
	Pennsylvanian	Fountain Fm.-arkose, ss, sh, ls	#Waubaunsee Gp.-ls
			*Shawnee-Douglas Fms-.,sh,ss.ls
			*Lansing-Kansas City Gps.-ls
			Pleasanton Gp.-ls
			*Marmaton Gp.- ls
			*Cherokee Gp.-ls
		Glen Eyrie Sh. Mbr.-sh	#Atoka age unnamed- ls
			#Morrow age unnamed-ss,sh.
	Mississippian	Leadville Ls.-ls	St. Louis Ls.-ls
			Salem Fm.-ls
			Warsaw Fm.-ls
			#Osage Gp.-ls
			#Kinderhook Gp.-ls
	Ordovician	#Fremont Ls.-ls	
		#Harding Ss.-ss	
		#Manitou Ls.-ls	#Arbuckle Gp.-ls
	Cambrian	#Peerless Dolo.-dol.	#Reagan Ss.-ss
		Sawatch Quartzite-ss	

* Currently producing # Potentially productive

extension of the Central Kansas uplift, and they terminate to the north in the Black Hills uplift.

The Denver basin accounted for over 95% of the 100 Bcf of gas that was produced during 1985 in this province. The amount produced from the Las Animas arch was slightly less than 4%. One-half Bcf was produced from the Chadron arch, all of it in South Dakota.

Probable resources are expected to be found in field extensions of Cretaceous and Pennsylvanian sediments. In order of estimated magnitude of future potential, starting with the largest, they are: the "J" sandstone, Niobrara chalk, Codell, Plainview-Lytle, Terry and Hygiene, Morrow, Leo, and "D" sandstones. Possible resources are expected to be discovered in the same rock units. Field sizes should range from one-half to 500 Bcf with most of them averaging 2 to 50 Bcf. Production of Possible resources should be concentrated within the deep, axial section of the Denver basin, the southeast Colorado segment of the Las Animas arch and the South Dakota portion of the Chadron arch. Shallower pool, and, to a lesser extent, deeper pool discoveries will be significant. Speculative resources will most likely come from presently unproductive sandstones, siltstones and carbonates of the Upper Cretaceous and Upper Paleozoic ages. Many of these reservoirs will be shaley, and have low permeability.

Reservoir rocks. The only dry gas in this province comes from the tight reservoirs of the Niobrara Formation chalks along the eastern side of the Denver basin and from adjacent parts of the Las Animas and Cambridge arches. This "tight gas" accounted for about 13% of the province's 1985 gas production. The most significant reservoir rock in the basin is the Lower Cretaceous "J" sandstone of the Dakota Group, also a tight reservoir. The non-associated, wet gas produced from the "J" sandstone at the Wattenberg field alone accounted for 27% of the 1985 production. At Wattenberg field, large volumes of gas are also produced from deeper and shallower pool sandstones and fractured marls over a 4,000 foot interval. In the western and deepest part of the Denver basin, important reservoirs are located in the Upper Cretaceous sediments. They include the shelf and offshore marine sandstone complexes of the Terry, Hygiene and Codell sandstones and the fractured marls and chalks of the Niobrara Formation. These reservoirs accounted for 22% of the gas produced in 1985. Over 21% of the province's gas came from numerous, rather small (about 2 to 5 Bcf average size), "J" sandstone and, to a lesser extent, "D" sandstone fields in Colorado and Nebraska. These reservoirs have porosities that approach 30% on the shallow east flank and become progressively less porous toward the deeper west. Minor gas reservoirs are found in the Upper Cretaceous Parkman sandstones and Greenhorn limestones, the Lower Cretaceous Plainview-Lytle sandstones and the Permian Lyons sandstones.

Very few wells in the Denver basin have been drilled below the Lower Cretaceous sediments. A current play, centered in southwest Nebraska and northeast Colorado, is aimed at testing upper Paleozoic rocks. Some excellent oil reservoirs have been found in Permian- and Pennsylvanian-age clastics and carbonates. A little associated gas has also been discovered. Other potential reservoirs exist in tight, fractured marls, siltstones and shales of Cretaceous age and in the Mississippian, Devonian, Ordovician and Cambrian age sediments.

The principal gas reservoir on the Las Animas arch is the Lower Pennsylvanian Morrow sandstone which contributed slightly less than 4% of the gas produced in the province during 1985. Some minor gas is associated with the multiple oil reservoirs, dominantly carbonates, ranging from Mississippian through Permian in age.

Along the Chadron-Cambridge arches, very little associated gas comes from the many oil fields producing within Pennsylvanian carbonates and clastics. One exception is the Leo sandstones (Minnelusa equivalent) of Pennsylvanian age from which associated gas is produced in South Dakota. Several undeveloped accumulations of shallow gas have been found in the Niobrara Formation chalks and in the Dakota Group sandstones.

Traps. In the Denver basin, the major traps are formed by rapid stratigraphic changes, but important accumulations are also derived from structures, structural-stratigraphic features and fractures. Marine shales form the principal seals. Anticlines and faulted structural traps are confined to the mountain fronts in the west, and to the east central and east portions of the basin. The eastern, shallow Niobrara Formation chalks produce gas from complex, highly faulted structures capped by a 10- to 30-foot thick bentonite seal. Fractures have enhanced production from the low permeability rocks in the deep Denver basin and from the tight, shallow chalks to the east.

Basement tectonic movements formed the structures, caused the fracturing and controlled the depositional patterns in the sediments. The Cretaceous-age sandstones were deposited in a broad variety of clastic environments ranging from coastal and deltaic to offshore marine.

Morrow sandstones were deposited in valley-fill, estuarine and marine shelf environments in the Las Animas arch area. The Leo sandstones were part of a coastal eolian/sabkha depositional system. Carbonate biohermal and structural traps are prevalent in the Permian- through Mississippian-age fields along the Las Animas and Chadron arches.

Potential source rocks. Cretaceous marine shales are the dominant source rocks for the region. The major ones are found in the Niobrara Formation and the Mowry and Huntsman Shales. Also contributing hydrocarbons are the Carlile, Granerous and Skull Creek shales and the Greenhorn Limestone. These source beds are mature only in the deepest portion of the Denver basin, generally below 6,000 feet. Igneous thermal activity related to the Colorado Mineral Belt of the Transcontinental Arch also contributed to source rock maturity. Some gas has migrated updip to fields over 100 miles to the east from the downdip mature areas. Vertical migration of over 2,500 feet has also been noted. The shallow eastern Niobrara formation gas has a biogenetic source rather than a thermal one. Permian and Pennsylvanian cyclic black marine shales constitute the source beds for the Las Animas and Chadron arches and for the Paleozoic production in the Denver basin.

P-540, UINTA AND PICEANCE BASINS, PARK BASINS AND EAGLE BASIN

This province contains six basins: Unita, Piceance, Eagle, North Park, Middle Park and South Park. Hydrocarbons produced in the region are oil, associated/dissolved gas and non-associated gas. Large amounts of both oil and gas are produced in the Uinta basin. The Piceance basin is predominantly a gas province and may have the potential to be a nearly continuous gas field similar to that which occurs in the San Juan basin.

The Uinta basin is the largest and most highly productive portion of the province. It is bounded on the north by the Uinta Mountains, on the west by the Wasatch Range, on the south by the San Rafael swell and Uncompahgre uplift, and on the east by the Douglas Creek arch. The axis of this asymmetric, east-west trending basin lies in the northern portion of the basin. Sediments are more than 30,000 feet thick in this region; more than 11,000 feet of these are Tertiary continental and lacustrine deposits. Major downwarping of the basin occurred during the late Cretaceous and Eocene.

The Piceance basin is the second largest and second most productive portion of the province. It is bounded on the west by the Douglas Creek arch, on the north by the Axial Basin anticline, on the east by the White River uplift and on the southwest by the Uncompahgre uplift. Up to 27,000 feet of sedimentary rocks were deposited in the deepest portion of the basin. Most fields in this region produce from more than one interval; some have up to six reservoirs. Rangely field, which lies on the Douglas Creek arch, is the only giant oil and gas field in Colorado.

Eagle and North Park basins continue to be areas of exploration interest. Small amounts of both oil and gas are produced in these basins. South Park and Middle Park contain no production at this time. South Park has some potential for production. Middle Park has very little potential.

Cumulative gas production from this province exceeds 3,000 Bcf. More than 75% of the production comes from reservoirs ranging from Early Cretaceous to Early Tertiary in age. In the Uinta and Piceance basins, only 10-15% of the potentially productive area has been adequately tested through the Cretaceous section. Possible Cretaceous objectives remain virtually undrilled in the deeper portions of the Uinta basin, while large tracts underlain by potential Tertiary and Cretaceous reservoirs remain untested in the central Piceance basin. Short-range future activity will focus on these plays as well as extension, in-field and new pool exploratory drilling within existing fields. Recent gas-condensate discoveries within Pennsylvanian-aged rocks should stimultate drilling activity for these reservoirs, particularly along basin margins.

P-540, UINTA-PICEANCE BASINS, PARK BASINS AND EAGLE BASIN
Generalized Stratigraphic Section

AGE	FORMATION			GENERAL LITHOLOGY
	West		East	
Cenozoic				
Oligocene		Duchesne River Fm.		sandstone, shale
Eocene		*Uinta Fm.		sandstone, shale
		Green River Fm.		shale, marl, oil shale
Paleocene-Eocene	*Wasatch Fm.		Coalmont Fm.	sandstone, shale, coal
	Ohio Creek Fm.	Fort Union Fm.	South Park Fm.	sandstone, shale
Paleocene		North Horn Fm.		sandstone, shale
Mesozoic				
Cretaceous				
Late	Lance Fm.		Laramie Fm.	shale, sandstone, coal
		Fox Hills Fm.		sandstone
		Lewis Shale		shale
	*Mesaverde Group	Mancos Sh.	Pierre Sh.	ss.,shale,ls
		*Niobrara Fm.		shale, marl
		*Carlile Sh.		shale
		Codell Ss. Mbr.		sandstone
		Greenhorn Ls.		limestone
		*Frontier Fm.		sandstone, shale
Early		Mowry Shale		shale
		*Dakota (Muddy) Ss.		sandstone, shale
		Thermopolis Sh.		shale
	*Cedar Mountain Fm.		Burro Cyn.Fm.	sandstone, shale
Jurassic		*Morrison Fm.		sandstone, shale
	Curtis Fm.	Summerville Fm.		shale, limestone
		*Entrada Ss.		sandstone
	Twin Creek . Limestone	Carmel Fm.		limestone, shale
	Nugget Ss.			sandstone
Triassic-Jurassic		Navajo Ss.		sandstone
Triassic		Chinle Fm.		shale, sandstone
		*Shinarump Mbr.		sandstone,
conglomerate				
	Thaynes Ls.	Woodside Sh.	*Moenkopi Fm.	ls., shale, ss
Paleozoic				
Permian	Park City Fm.	Phosphoria Fm.	*State Bridge Fm.	limestone, shale
	White Rim Fm.		Garo Ss.	sandstone
Penn.-Permian	*Weber Ss.		Maroon Fm.	sandstone, shale
			Eagle Vy.Fm.	evaporites
Pennsylvanian	Morgan Fm.	*Minturn Fm.	Gothic Fm.	ss., shale, ls
	Round Vy. Ls.	#Belden Sh.		limestone, shale
		Molas Fm.		shale

*Currently producing #Potentially productive

P-540, UINTA-PICEANCE BASINS, PARK BASINS AND EAGLE BASIN

Generalized Stratigraphic Section (continued)

AGE LITHOLOGY	FORMATION			GENERAL
	West		East	
Mississippian	Doughnut Fm.		Manning Cyn. Fm.	shale
	*Humbug Fm.			sandstone
	Deseret Ls.		#Leadville Ls.	limestone
	Gardison Ls.	Madison Ls.		limestone
Devonian - Miss.		Chaffee Group		sandstone, dolomite
		Gilman Ss.		sandstone
		Dyer Dolo.		dolomite
		Parting Fm.		sandstone
Ordovician		Fremont Ls.		limestone, dolomite
		Harding Ss.		sandstone
		Manitou Fm.		limestone
Cambrian		Doterso Fm. - Peerless Fm.		limestone
	Lodore Ss.		Sawatch Quartzite	sandstone
	Maxfield Ls.			limestone
	Ophir Fm.			shale
	Tintic Quartztite			sandstone

* Currently producing # Potentially productive

Probable resources are expected to be found mostly in field extensions and new pool discoveries within existing fields. Possible resources are to be found in fields ranging in size from 1 to 200 Bcf with most fields falling within the 2 to 20 Bcf range. The size of fields for Speculative resources should range from 10 to 1,000 Bcf with an average field size of around 100 Bcf.

Reservoir rocks. The Eocene Green River and Wasatch Formations are the primary reservoirs in the Uinta basin as well as being important units in the Piceance basin. In the Park basins some production is from the Paleocene Coalmont Formation. Cretaceous reservoirs in this province are the Mesaverde, Mancos, Frontier, Codell, Dakota, Muddy and Lakota sandstones. Some fields produce from fractured Pierre and Niobrara intervals. Jurassic sandstone reservoirs are the Morrison and Entrada Formations. Productive Paleozoic units are the Permian Phosphoria Formation, Pennsylvanian-Permian Weber Sandstone, and Pennsylvanian Minturn Formation.

Traps. Stratigraphic traps are very important in this province, including deltaic lenses, channel and bar sands, permeability pinchouts and asphalt seals. Present production from stratigraphic traps is confined to Cretaceous and Paleocene rocks. Traditional structural traps in the province are fault traps, anticlines and faulted anticlines which affect all stratigraphic intervals. Unconformity surfaces form traps in the Weber and Phosphoria Formations.

Potential source rocks. Source rocks in the Uinta, Piceance and Eagle basins range in age from Mississippian to Eocene. All are mature in certain areas. These source units are the Eocene Wasatch and Green River formations; Upper Cretaceous Mesaverde Group and Mancos Shale; Pennsylvanian Phosphoria and Belden shales, Mississippian Manning Canyon Shale and Deseret Limestone. Possible source rocks for the Park basins are the Cretaceous Niobrara, Greenhorn, Mowry and Thermopolis formations.

P-545, SAN JUAN MOUNTAINS, SAN LUIS BASIN, LAS VEGAS-RATON BASIN, SIERRA GRANDE UPLIFT

This region of southern Colorado and northeastern New Mexico contains two structural basins, two structural arches and two mountain ranges. Present production is restricted to minor amounts of non-associated gas which is scattered through the province. Most of the production is located in the northern part of the Las Vegas-Raton basin. Two fields are located on the Apishapa uplift and one field lies at the southern nose of the Uncompaghre Mountains in Ouray County, Colorado. The Las Vegas-Raton basin contains over 7,200 feet of sediments ranging in age from Devonian to Holocene. The San Luis basin is considered a northern extension of the Rio Grande Rift and is cross-cut by numerous fault blocks. Total sediment thickness, which may exceed 20,000 feet, varies greatly over these blocks. Much of the San Luis basin and the Sierra Grande arch are covered with volcanics. Carbon dioxide is produced from Jurassic sandstones and Pennsylvanian-Permian arkoses in Harding County, New Mexico. Helium, nitrogen and carbon dioxide are produced from the Permian at the Model Dome field on the Apishapa uplift.

Reservoir rocks. Potential reservoir rocks range in age from Pennsylvanian to Paleocene. They include the Cretaceous-Paleocene Raton Formation; the Upper Cretaceous Vermejo Formation, Trinidad Sandstone, fractured Niobrara Formation, Codell Sandstone Dakota equivalents; the Jurassic Entrada Sandstone; the Permian Glorieta Sandstone; the Pennsylvanian-Permian Sangre de Cristo Formation; and the Pennsylvanian Madera Limestone.

Traps. Stratigraphic traps may be found in most intervals. These include sandstone lenses and porosity pinchouts. Structural traps include anticlines, faulted anticlines and reverse faults. Combinations of these traps may exist.

Potential source rocks. The most likely source rocks in the province are the Raton and Vermejo Formations and Colorado Group. Paleozoic carbonate rocks may also be source beds in parts of the province.

P-550, PARADOX BASIN

This province covers most of southeastern Utah and part of southwestern Colorado and contains three major producing regions: the Paradox basin, the Uncompahgre uplift and the San Rafael Swell. The Paradox basin is a sedimentary basin containing more than 24,000 feet of sedimentary rocks ranging in age from Cambrian to Tertiary. The basin is bounded on the west and southwest by the San Rafael Swell and the Monument uplift, on the southeast by the Four Corners Platform, and on the east and northeast by the Uncompahgre uplift. Major downwarping of the basin occurred during the Pennsylvanian and Permian Periods. Carbon dioxide and helium are also produced in the province.

Reservoir rocks. Major production in the Paradox basin is from the Pennsylvanian Hermosa Group, Paradox Formation and the Mississippian Leadville Formation. Production from the Uncompahgre uplift is mostly from the Cretaceous Dakota Sandstone, fractured Mancos Shale, Cedar Mountain Sandstone, and Castlegate Member of the Mesaverde Formation; from the Jurassic Salt Wash Member of the Morrison Formation and Entrada Sandstone; and from the Permian Coconino Sandstone. On the San Rafael Swell, production has been from the Upper Cretaceous Ferron Member of the Mancos Shale, the Jurassic Navajo Sandstone and the Triassic Moenkopi Limestone. Other reservoir rocks in the province include the Triassic Sinbad Limestone and Timpoweap Limestone, the Permian Kaibab Limestone and White Rim Sandstone, and the Devonian McCracken Sandstone.

Traps. Stratigraphic traps are common in the Paradox basin. These include biohermal carbonate mounds and porosity changes, and are more common in the southern portion of the basin. Salt anticlines and faulted anticlines are more common in the northern part of the basin. Sub-salt fault blocks are a major trapping mechanism. On the Uncompahgre uplift and San Rafael Swell, anticlines and porosity pinchouts are trapping mechanisms.

P-545, SAN JUAN MOUNTAINS, SAN LUIS BASIN, LAS VEGAS-RATON BASIN AND SIERRA GRANDE UPLIFT

Generalized Stratigraphic Section

AGE	FORMATION		GENERAL LITHOLOGY
	West	East	
Cenozoic			
Holocene			
Oligocene		Farisita Congl.	conglomerate
Eocene		Huerfano Fm.	shale, sandstone
		Cuchara Fm.	sandstone, shale
Paleocene	Animas Fm.	Poison Canyon Fm.	arkose, sandstone
Late Cret.-Paleocene		#Raton Fm.	sandstone, shale, coal
Mesozoic			
Late Cretaceous	Kirkland Sh.		shale, sandstone
	#Fruitland Fm.	#Vermejo Fm.	shale, sandstone, coal
	Pictured Cliffs Ss.	#Trinidad Ss.	sandstone
	Lewis Sh.	Pierre Shale	shale
	Mesaverde Gp.	Colorado Gp.	shale, sandstone, limestone
	Mancos Sh.	Niobrara Fm.	marl, shale, limestone
		Benton Gp.	
		Carlile Shale	shale, sandstone
		Codell Ss. Mbr.	sandstone
		Greenhorn Ls.	limestone, shale
		Graneros Sh.	shale
Early Cretaceous		*Dakota Ss.	sandstone, shale
	Burro Canyon Fm.	Purgatoire Fm.	sandstone, shale
Jurassic		Morrison Fm.	shale, sandstone
	Ralston Creek Fm.	Exeter Ss.	limestone, sandstone
	Wanakah Fm.		sandstone
		Entrada Ss.	sandstone
Triassic		Johnson Gap Fm.	limestone
		Dockum Gp.	shale, sandstone
		Sheep Pen Ss.	sandstone
	Chinle Fm.	Sloan Canyon Fm.	shale, sandstone
	Dolores Fm.	Santa Rosa Ss. Travessor Fm.	sandstone, shale
		Baldy Hill Fm.	shale
Paleozoic			
Permian	Bernal Fm.	Whitehorse Fm.	sandstone
	Cutler Fm.	San Andres Ls.	limestone
		*^{1}Glorieta ("Lyons") Ss.	sandstone
		Yeso Fm.	shale, sandstone
Penn.-Permian	Abo Fm.	Sangre de Cristo Fm.	arkose, sandstone, shale
Pennsylvanian	#Rico Fm.		sandstone
	#Magdalena Gp.	Hermosa Fm.	limestone, shale
	Madera Fm.		limestone
	Sandia Fm.		shale
Mississippian	Meramac Gp.	Terrero Fm. Leadville Ls.	limestone, shale, sandstone
		Espiritu Santu Fm.	limestone

* Currently producing *^{1} Helium, nitrogen, CO_2, etc. # Potentially productive

P-550, PARADOX BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Mesozoic		
Cretaceous		
Late	*Mesaverde Gp.	sandstone and shale
	*Mancos Sh.	shale
	Greenhorn Ls. Mbr.	limestone
	Graneros Sh. Mbr.	shale
	*Dakota Ss.	sandstone
Early	*Burro Canyon Fm.	sandstone
Jurassic	*Morrison Fm.	shale and sandstone
	San Rafael Gp.	
	Bluff Ss.–Junction Creek Ss.	sandstone
	Summerville Fm.	shale and sandstone
	Curtis Fm.	shale
	Entrada Fm.	sandstone
	Carmel Fm.	shale
	Glen Canyon Gp.	
	Navajo Fm.	sandstone
	Kayenta Fm.	red beds
Triassic	Wingate Fm.	sandstone
	Chinle Fm.	red beds
	Church Rock Mbr.	
	Owl Rocky Mbr.	
	Petrified Forest Mbr.	
	Moss Back Mbr.	
	Monitor Butte Mbr.	
	Temple Mtn. Mbr.–Shinarump Mbr	conglomerate
	Moenkopi Fm.	red beds
Paleozoic		
Permian	Cutler Fm.	arkoses
	*White Rim Ss.--DeChelly Ss.	sandstone
	Organ Rock Tongue	
	Cedar Mesa Ss. Mbr.	sandstone
	Halgaito Tongue–Elephant Canyon Fm.	
Pennsylvanian	Hermosa Gp.	
	*Honaker Trail Fm.	limestone and sandstone
	*Paradox Fm.	evaporites, carbonates
	Pinkerton Trail Fm.	limestone
	Molas Fm.	red shale
Mississippian	*Leadville Fm.	dolomite and limestone
Devonian	Ouray Fm.	dolomite
	Elbert Fm.	dolomite and shale
	*McCracken Ss. Mbr.	sandstone
	Aneth Fm.	shale and limestone
Silurian	missing	
Ordovician	missing	
Cambrian	Lynch Dolo.	dolomite
	Muav Ls.	limestone
	Bright Angel Sh.--Ophir Sh.	shale
	Ignacio Quartzite	quartzite

* Currently producing   No future productive reservoirs, not presently productive, are anticipated

Source rocks. The source of hydrocarbons appears to be mostly from Pennsylvanian-age rocks, especially the black shales interbedded with salt in the Paradox Formation. The Cretaceous Mancos Shale and Frontier Formation are the probable source beds for much of the Mesozoic production.

Future exploration. This province is in an early stage of exploration. Other reservoir intervals in addition to the Pennsylvanian rocks need to be examined in the Paradox basin, especially the Ferron Sandstone Member of the Mancos Shale, and the Glen Canyon Group, the White Rim Sandstone, Kaibab and Coconino Formations. There are probably additional salt anticline traps and algal mounds as well as other structural traps and updip pinchouts to be discovered. Possible traps also lie beneath laccolithic intrusions in the region.

Accumulations in the Pennsylvanian biohermal mounds will probably be in the 1 to 25 Bcf range, while those in the Mississippian structural traps should be in the 20 to 300 Bcf range. Accumulations in the Permian Cutler and Pennsylvanian Honaker Trail formations should be in the 5 to 50 Bcf range.

P-555, SAN JUAN BASIN

The San Juan basin is one of the major gas provinces of the United States. It is bounded on the south by the Zuni uplift, on the east by the Defiance uplift, on the north by the San Juan uplift and on the east by the Nacimiento uplift. This structural basin covers 15,000 to 20,000 square miles and contains up to 15,000 feet of sedimentary rocks.

In the neighborhood of 20,000 wells have been drilled in the basin, of which approximately 17,000 are gas wells. Very little exploration drilling below the Cretaceous has been done outside of the Barker Dome Penn-Paradox and virtually nothing has been completed below 15,000 feet.

Probable resources are anticipated to be associated with established fields and will be discovered by extension of those fields. Due to a lack of aggressive "wildcatting" throughout the basin, the Possible category is separated from the Probable category, in general, on the higher risk of discovery as distance increases from known production. Speculative resources have not been considered in the San Juan basin.

Reservoir rocks. Production in the basin is mostly from Cretaceous sandstones. Upper Cretaceous reservoir rocks include the Pictured Cliffs Sandstone, the Fruitland Formation, the Chacra Sandstone, the Mesaverde Group (Cliff House and Point Lookout Members) and the Gallup Sandstone. With fracturing, some oil has been produced from the Mancos Shale. The Dakota Group is the dominant Lower Cretaceous reservoir in the basin. There is limited production from the Jurassic Entrada Sandstone and Morrison Formation. The Pennsylvanian Hermosa Formation produces oil, natural gas and helium along the western flank of the basin. Helium is found in the Devonian Ouray Limestone.

Traps. Stratigraphic trapping dominates in the basin. The specific trapping conditions include sandstone lenses, channels and bars and are influenced by differential compaction related to ancient topographic highs. The sedimentary rocks in the area are largely underpressured. Hydrodynamic traps have been recognized in the Gallup and Entrada Sandstones. Anticlinal traps are confined to the southwestern flank of the basin. Hydrodynamic conditions together with low permeability of reservoir rocks and the mechanism of gas generation are the main factors which have resulted in the formation of one giant gas field in the Cretaceous rocks of the central portion of the basin.

Potential source rocks. The Upper Cretaceous Mancos Shale and the Menefee Member of the Mesaverde Formation are the most likely sources for hydrocarbons found in the Upper Cretaceous reservoirs. The upper Jurassic Todilto Formation may have been a source bed for the Dakota Group and for the Entrada Sandstone. The Hermosa Formation is another likely source bed, as are the coal beds in the Fruitland Formation.

Producing trends. The Hogback monocline on the northwestern flank of the basin is a striking structural feature with several producing fields. Anticlines are confined to the rims of the basin and no folding has been detected in the central portion of the basin. Upper Cretaceous rocks in the central portion constitute basically one giant gas field, the Basin Dakota field, with a diameter of 100 miles and covering an area of over one million acres.

P-555, SAN JUAN BASIN
Generalized Stratigraphic Section

AGE	FORMATION		GENERAL LITHOLOGY
	West	East	
Mesozoic			
Cretaceous			
Late	Kirtland Sh.		shale
	Farmington Ss. Mbr.		sandstone
	*Fruitland Fm.		shale, sandstone, coal
	*Pictured Cliffs Ss.		sandstone
	Lewis Sh.		shale
	*Mesaverde Gp.		
	Cliff House Ss.	*Chacra Ss.	sandstone
	Menefee Fm.		shale, sandstone, coal
	Point Lookout Ss.		sandstone
	Mancos Sh.		shale
	*Dakota Ss.		sandstone
Early	Burro Canyon Fm.		sandstone and shale
Jurassic	*Morrison Fm.		shale and sandstone
	#Bluff Ss.		sandstone
	Summerville Fm.		shale and sandstone
	Todilto Ls.		limestone and evaporites
	*Entrada Ss.		sandstone
	Carmel Sh.		shale
	#Navajo Ss.		sandstone
	Kayenta Fm.		red beds
Triassic	#Wingate Ss.		sandstone
	Chinle Fm.		red beds
	#Shinarump Congl.		conglomerate
	Moenkopi Fm.		red beds
Paleozoic			
Permian	DeChelly Ss.	San Andres Ls.	sandstone, limestone
	#Cutler Fm.	Glorieta Ss.	sandstone
	(arkoses)	Yeso Fm.	shale, dolomite, sandstone
		Abo Fm.	red beds
Pennsylvanian	*Hermosa Fm.	Madera Ls.	limestone
	Molas Fm.	Sandia Fm.	shale
Mississippian	Leadville Ls.		limestone and dolomite
Devonian	*[1]Ouray Ls.		dolomite
	McCracken Ss.		sandstone
	Aneth Fm.		shale and limestone
Silurian	missing		
Ordovician	missing		
Cambrian	Ignacio Quartzite		quartzite

* Currently producing   *[1]Helium   #Potentially productive

in which production occurs at depths shallower than 8,000 feet. Production in the Pictured Cliffs Sandstone is from elongate, northwest-trending sandstone stringers encased in shales.

Future exploration. Potential reservoir rocks below the Dakota Group include the Pennsylvanian section and the Jurassic. The Basin Dakota field may extend into Sandoval County. The southern and eastern flanks of the basin warrant further exploration.

P-560, SOUTHERN BASIN AND RANGE PROVINCE

This province covers southern Arizona and southwestern New Mexico. Production of natural gas or oil has been established in Otero County, New Mexico, but is currently shut in. Carbon dioxide has been produced from the Estancia field in Torrance County, New Mexico. This area is considered a frontier region for petroleum exploration whose potential has not yet been determined.

Southern Arizona is a region of Precambrian rocks, lava flows and alluvial sediments. It has been postulated that the Western Thrust Belt extends from southernmost Nevada across southern Arizona, but this has not been confirmed by the results of limited drilling. If the Thrust Belt does exist in this region, then the potential for future production would be greatly increased. Additionally, discoveries of natural gas in Mexico, south of southwestern Arizona, raise some possibility for the establishment of production in westernmost Arizona. The Pedregosa basin of southeastern Arizona and southwestern New Mexico contains over 14,500 feet of sedimentary rocks and, thus, has some potential for production.

Central and southern New Mexico contains five sedimentary basins and the Lucero shelf. Sedimentary rocks representing all periods of the Paleozoic Era are present together with Jurassic and Cretaceous sedimentary rocks. Central New Mexico contains a thick Miocene-Pliocene sequence of continental sedimentary rocks and volcanics. The Tularosa (Orogrande) and Jornada del Muerto basins contain over 7,000 feet of sedimentary rocks. The Tularosa basin contains prospective Pennsylvanian biohermal limestones.

Reservoir rocks. Potential reservoir rocks in central New Mexico include the Cretaceous Dakota Formation and Gallup Sandstone; the Jurassic Entrada Sandstone; the Permian Glorieta Sandstone and San Andres Limestone; the Pennsylvanian-Permian Sangre de Cristo Formation; and the Pennsylvanian Hermosa Formation and Madera Limestone. South-central New Mexico reservoirs include the Pennsylvanian Magdalena Group; the Mississippian Lake Valley Formation; the Silurian Fusselman Formation; and the Ordovician El Paso and Montoya Formations as well as undifferentiated Cretaceous, Permian and Pennsylvanian rocks. Potential reservoirs in the Pedregosa basin range in age from Cambrian to Early Cretaceous and include the Lower Cretaceous Mojado and the upper Bisbee Group; the Permian Colina, Epitaph, Concha and Rainvalley Formations; the Pennsylvanian Horquilla and Earp Formations; the Mississippian Paradise and Escabrosa Formations; the Devonian Martin Formation: the Silurian Fusselman Formation; the Ordovician El Paso and Montoya formations; and the Cambro-Ordovician Bliss Sandstone and Abrigo Formation.

Traps. Potential traps are both structural and stratigraphic. Anticlinal and faulted anticlinal traps are present. Stratigraphic traps include bioherms, sandstone channels and lenses, carbonate-evaporite sequences and carbonate-red bed sequences. Thrust faulting, shear zones and block faulting form potential traps in southern Arizona.

Potential source rocks. Potential source rocks in central New Mexico are the Cretaceous Mancos Shale and Colorado Group, Jurassic Todilto Limestone, Permian San Andres Limestone, and Pennsylvanian Madera Formation. In south-central New Mexico, the prospective source rocks are the Cretaceous Mancos Shale, Permian Hueco-Colina Formations, Pennsylvanian Gray Mesa Formation, Mississippian Lake Valley-Escabrosa Limestone and Devonian Percha Formation. In southern Arizona and southwestern New Mexico, possible source rocks include the Permian Colina, Epitaph, Concha, Scherrer, and Rainvalley Formations; Pennsylvanian Horquilla Formation; Mississippian Paradise Formation; and Devonian Percha Formation.

P-560, SOUTHERN BASIN AND RANGE PROVINCE
Generalized Stratigraphic Section

AGE	FORMATION AND LITHOLOGY			
	CENTRAL NM	SOUTHERN NM		SOUTHERN AZ
Cenozoic				
Miocene-Pleistocene		Santa Fe Gp.-ss,cong.		#Miocene?
Eocene	Galisteo Fm.-ss,sh			
Mesozoic				
Cretaceous				
Late	Mesaverde Fm.-ss,sh	#Gallup Ss.-ss		Ft. Crittenden Fm.-cong
		Mancos Sh.-sh		Colorado Fm.-ss
				Beartooth Fm.-ss
Early		#Dakota-Sarten Ss.-ss		#Bisbee Gp.-sh,ss,ls
				#Mojada Fm.-ss
				Mural Fm.-ls
Jurassic	Todilto Fm.-ls,sh			
	#Entrada Ss.-ss			
				"Canelo Hill Vol."-ss
				Gardner Canyon Fm.-sh
Triassic		Dockum Gp.-sh,ss		
		Chinle Fm.-sh		
		Santa Rosa Ss.-ss		
Paleozoic				
Permian	Bernal Fm.-sh			Naco Gp.-ls,ss,sh
		#San Andres Fm.-ls		#Rainvalley Fm.-ls
		#Glorieta Ss.-ss		#Concha Ls.-ls
		Yeso Fm.-sh,ls,ss		Scherrer Fm.-ss
				#Epitaph Dolo.-dolo
Penn.-Perm.	#Sangre de Cristo-Abo Fm.-ss,sh,arkose			#Colina Ls-ls
			Hueco-Bursum Fm.-ls	Earp Fm.-sh
Pennsylvanian	Magdalena Gp.- #Hermosa Fm.-		Panther Seep Fm.-ls,sh	#Horquilla Ls.-ls
	#Madera Fm.-ls		#Lead Camp Ls.-ls	
	Gray Mesa Mbr.-ls			
	Sandia Fm.-sh			
				Black Prince Ls-ls
Missisippian			Helms Fm.-sh	
	Tererro Fm.-ls		#Rancheria Fm.-ls	#Paradise Fm.-ls
	Espirito Santo Fm.-ls		#Lake Valley Fm.-ls	#Escabrosa Gp.-ls
Devonian		Caballero Fm.-ls		
		"Percha" Sh-sh	Martin Fm.-ls	
		Sly Gap Fm.-sh		
		Oñate Fm.-sh		
Silurian		#Fusselman Dolo.-dolo		#Fusselman Dolo.-dolo
Ord.- Silurian		Valmont Dolo.-dolo		
Ordovician		#Montoya Fm.-ls		#Montoya Fm.-ls
		#El Paso Fm.-ls		#El Paso Fm.-ls
Cambro-Ordovician		#Bliss Fm.-ss		#Bliss Fm.-ss
				#Abrigo Fm.-sh
				Bolsa Quartzite-ss

Potentially productive

P-565, PLATEAU PROVINCE AND BLACK MESA BASIN

This province covers northern Arizona and part of southern Utah. The province includes the Colorado Plateau, the Black Mesa basin and the Defiance uplift. Production in the province is presently confined to the Defiance uplift. The Colorado Plateau consists of a thick series of sedimentary rocks which have undergone relatively little deformation since their deposition. The section does not contain favorable potential source rocks and there are relatively few potential traps, so the Colorado Plateau has little or no potential for future natural gas production. The Black Mesa basin is a structural downwarp instead of a depositional sedimentary basin and also has little or no potential for future natural gas production.

Reservoir rocks. Current production comes from rocks ranging in age from Devonian to Cretaceous. The reservoir formations include Cretaceous sandstones; the Permian Coconino Sandstone; the Pennsylvanian Paradox and Naco Formations; the Mississippian Leadville Limestone; and the Devonian Aneth and McCracken Formations. All intervals produce both oil and natural gas. Helium is also produced from both the Coconino Sandstone and the Devonian reservoirs.

Traps. Biohermal limestones are common in the Aneth Formation. Variable porosity and permeability is a common stratigraphic trap. Both anticlines and faulted anticlines are prospective targets. Production has also been developed in units adjacent to a Tertiary sill.

Potential source rocks. The probable source beds for the province are carbonate rocks, including the Pennsylvanian Paradox and Naco Formations and the Devonian Aneth and Martin Formations.

Future exploration. Much of the province apparently has little potential for natural gas production. The Defiance uplift, however, has been sparsely explored and, undoubtedly, contains more stratigraphic traps. Mesozoic intervals have been largely ignored and contain potential reservoirs.

P-570, SWEETGRASS ARCH AND CENTRAL MONTANA

This region covers the central portion of Montana. It contains a thick series of sedimentary rocks of Mesozoic and Paleozoic age, including both clastic and carbonate rocks. Numerous domes, arches, and young intrusive mountain complexes dot the province. Both associated/dissolved and non-associated gas are produced in this region.

Reservoir rocks. Numerous sandstone reservoir rocks of Cretaceous age include the Judith River and Eagle Members of the Pierre Shale, the Bow Island Member of the Blackleaf Formation, Frontier Formation, Cat Creek, Viking, Moulton, Sunburst, Lakota, and Cutbank Sandstones. On the Sweetgrass arch, the Jurassic Swift and Sawtooth Formations of the Ellis Group are productive. Paleozoic units of interest are the Pennsylvanian Amsden Group and Tyler Formation; Mississippian Madison Group; and Devonian Nisku (Birdbear) Formation.

Traps. Anticlines and domes form traps for all stratigraphic intervals throughout the region. Faults are numerous due to various tectonic events in the area and provide traps for many units. In all Cretaceous units and in the Tyler Formation, traps occur in sandstone channels and lenses. Porosity variations occur in all intervals. In the Madison, buried topographic traps can be found. At various intervals, angular unconformities are the trapping mechanism. Hydrodynamic tilting of oil/water and gas/water contacts occurs in the south-central portion of the province.

Potential source rocks. Many Jurassic and Cretaceous units are potential source rocks. These are the Montana Group, Colorado Group, Inyan Kara Group, and Rierdon Formation. Paleozoic sources are probably the Tyler; Mississippian Heath and Lodgepole Formations; and Devonian-Mississippian Cottonwood Canyon and Bakken Formations.

P-565, PLATEAU PROVINCE AND BLACK MESA BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Eocene	Chuska Ss.	sandstone
Paleocene	Cedar Breaks Fm.	shale, limestone
Mesozoic		
Late Cretaceous	Kaiparowits Fm. – Mesaverde Gp.	sandstone, shale, coal
	Wahweap Fm.	sandstone, shale, siltstone
	Straight Cliffs Ss.- Tropic Sh. – Mancos Sh.	sandstone, shale
Early-Late Cretaceous	#Dakota Fm.	sandstone, shale
Jurassic	Morrison Fm.	shale, sandstone
	San Rafael Gp.	limestone, sandstone, shale
	Cow Springs Ss.	sandstone
	Entrada Ss.	sandstone
	Carmel Fm.	limestone
Triassic-Jurassic	Glen Canyon Gp.	sandstone, shale
	Navajo Ss.	sandstone
	Kayenta Fm.	sandstone
	Moenave Fm.	sandstone
	Wingate Ss.	sandstone
Triassic	Chinle Fm.	shale, siltstone, sandstone
	Church Rock Mbr.	shale and siltstone
	Owl Rocky Mbr.	shale and siltstone
	Petrified Forest Mbr.	shale and siltstone
	Monitor Butte Mbr.	shale and siltstone
	Shinarump Mbr.	sandstone
	Moenkopi Fm.	siltstone, sandstone
Paleozoic		
Permian	Kaibab Ls. – Hoskinnini Sh.	limestone, evaporites, shale
	Cutler Gp.	
	White Rim Ss.	sandstone
	Toroweap Fm.	limestone
	*[1]Coconino Ss. – De Chelly Ss.	sandstone
	Organ Rock Sh.	shale
	Cedar Mesa Ss.	sandstone
	Elephant Cnyn.Fm.-Halgaito Sh	shale
	Hermit Sh.	shale
	Esplanade Ss.	sandstone
Pennsylvanian Permian	Supai Gp.	sandstone, shale
Pennsylvanian	*Hermosa Gp. -Naco Gp.	limestone, dolomite, evap.
	Honaker Trail Fm.	sandstone and limestone
	*Paradox Fm.	limestone, evaporites
	Pinkerton Trail Fm.	limestone and shale
	Molas Fm.	shale

*Currently producing *[1]Inert gas, helium, etc. #Potentially productive

P-565, PLATEAU PROVINCE AND BLACK MESA BASIN
Generalized Stratigraphic Section (continued)

AGE	FORMATION	GENERAL LITHOLOGY
Mississippian	*Redwall Ls. – *Leadville Ls.	limestone
Devonian	Temple Butte Ls. – Ouray Fm.	limestone
	*Martin Fm. – Elbert Fm. – *Aneth Fm.	limestone, sandstone
	*McCracken Mbr.	sandstone
Cambrian	Lynch Dolo.	dolomite
	Tonto Gp.	limestone, sandstone, shale
	Muav Ls.	limestone
	Bright Angel Sh.	shale
	#Tapeats Ss.	sandstone
Precambrian	Grand Canyon Supergroup	sandstone, limestone, shale

* Currently Producing   *[1] Inert gas, helium, etc.   # Potentially productive

P-575, MONTANA FOLDED BELT

This region includes the northern projection of the Wyoming-Utah-Idaho Thrust belt. The configuration of the region was formed during the Laramide Orogeny in late Cretaceous and early Tertiary time. This deformation involving both Paleozoic and Mesozoic rocks, proceeded from west to east and progressively older sediments are involved to the west where more faulting has occurred. Major thrust faults, and imbricating minor thrusts, form a series of complexly folded and faulted thrust packages. Folding is common in all intervals. In various portions of the province, several older, northeast-trending, fault blocks affect the thickness of sediments.

Southwestern Montana underwent deformation of a different nature starting with major vulcanism during Campanian time. This was followed by emplacement of the Boulder batholith in latest Cretaceous time. The western portion of the province is made up of mountain belts.

Potential reservoir rocks. The Mississippian Madison Group is presently the only productive interval in this region. Other prospective units are Paleocene sandstones; the Cretaceous Fox Hills Sandstone, Eagle Sandstone Member of the Pierre Shale, Cloverly Formation, Cat Creek Sandstone, Lakota Formation, and Cutbank Sandstone Member of the Kootenai Formation. Possible Paleozoic reservoirs are the Pennsylvanian Quadrant Formation and Shedhorn Sandstone; and the Devonian Three Forks and Jefferson Formations. It is also possible that fractured Proterozoic Belt Supergroup strata will prove to be productive.

Traps. Major trapping mechanisms in the area are formed by thrust faults, folds and faulted folds. Traps occur in sandstone bars and channels within the Cretaceous and Tertiary units. Facies changes in Paleozoic carbonate rocks are a possible trapping mechanism.

Potential source rocks. Possible source rocks include Paleocene shales; the Cretaceous Montana and Colorado Groups; the Triassic Thaynes Formation; the Pennsylvanian Phosphoria Formation; and the Devonian-Mississippian Exshaw and Sappington Member of the Three Forks Formation. Possible Precambrian source beds include the black shale strata in the Belt Supergroup of Middle Proterozoic age.

P-570, SWEETGRASS ARCH AND CENTRAL MONTANA
Generalized Stratigraphic Section

AGE	FORMATION AND LITHOLOGY		
	Sweetgrass Arch		Central Montana
Cenozoic			
Paleocene-Eocene			Wasatch Fm.-ss, sh
Paleocene	"Willow Creek"-sh		Fort Union Fm.-ss, sh
Mesozoic			
Cretaceous			
Late	St. Mary River Fm.-sh		Hell Creek Fm.-ss
	Horsethief Ss. -ss		Fox Hills Ss.-ss
		Bearpaw Sh.-sh	
	Two Medicine Fm.-ss		Judith River Fm.-ss
			Claggett Sh.-sh
			*Eagle Ss.-Gammon Sh.-ss, sh
			*Virgelle Ss.-ss
			Telegraph Creek Fm.-ss, sh
		Marias River Fm.-sh, ls	
Early		*Blackleaf Fm.-ss, sh	
		*Bow Island (Viking) Ss.-ss	
	Inyan Kara Gp.-ss,sh		Kootenai Fm.-ss
	*Moulton Ss. – Sunburst Ss.-ss		Lakota Ss. Mbr.-ss
	*Lander Ss.-.ss		
	*Cutbank Ss.-ss		
Jurassic		*Morrison Fm.-sh, ss	
	Ellis Group-ss, ls,sh		
	*Swift Fm.-ss		*Swift Fm.-ss
	Rierdon Fm.-ls,sh		Rierdon Fm.-ls, sh
	*Sawtooth Fm.-sh		*Piper Fm.-sh, ss, ls
Paleozoic			
Pennsylvanian			Tensleep Fm.-ss
			*Amsden Fm.-ls, ss
			Tyler Fm.-sh
Mississippian		*Big Snowy Gp.-sh, ss	
		Heath Fm.-sh	
		Madison Gp.-ls	
	*Sun River Dol.	Charles Fm.-ls	
		*Mission Canyon Fm.-ls	
		Lodgepole Ls.-ls	
		Cottonwood Canyon Mbr.-ls	
Devonian-Mississippian		Bakken Sh.-sh	
Devonian		Three Forks Fm.-sh	
		Jefferson Gp.-ls	
		#Birdbear (Nisku) Fm.-ls	
		Duperow Fm.-ls	
		Souris River Fm.-ls	
Ordovician	Red River Fm.-ls		Bighorn Dolo.-dolo
Cambrian		Emerson Fm.-sh	Greve Creek - Deadwood Fms.
	Switchback Sh.-sh	Pentagon Sh.-sh	Park Sh.-sh
	Steamboat-Pagoda Ls.-ls		Meagher Ls.-ls
	Damnation Ls. – Dearborn Fm.-ls		Wolsey Sh.-sh
	Gordon Sh.-sh		
		#Flathead Ss.-ss	

* Currently producing # Potentially productive

P-575, MONTANA FOLDED BELT
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Paleocene-Late Cretaceous	#Fort Union Fm.	sandstone, shale
Mesozoic		
Cretaceous Late	Montana Gp.	
	Willow Creek Fm.	shale
	Beaverhead Congl.	conglomerate
	St. Mary River Fm.	shale
	#Fox Hills Fm.	sandstone
	Two Medicine Fm.-Pierre Sh.	shale, sandstone
	#Virgelle Ss.-Eagle Ss.	sandstone
	Telegraph Creek Fm.	shale
	Colorado Gp.	
	Marias River Shale	shale
Early	Blackleaf Fm.	shale
	Vaughn Sh.-Mowry Sh.	shale
	Dunkleburg-Muddy Ss.	sandstone
	Taft Sh.-Thermopolis Sh.	shale
	#Kootenai Fm.	sandstone, shale
	#Lakota-Cloverly-Cutbank-Sunburst Ss.	sandstone
Jurassic	Morrison Fm.	shale, sandstone
	Ellis Gp.	
	#Swift Fm.	sandstone
	Rierdon Fm.	limestone, shale
	Sawtooth Fm.	limestone, shale
Triassic	Thaynes Fm.	limestone
	Woodside Fm.	limestone
	Dinwoody Fm.	shale
Paleozoic		
Permian	Shedhorn Ss.	sandstone
	Phosphoria Fm.	shale
	Park City Fm.	limestone
Pennsylvanian	#Quadrant Fm.	sandstone
	Amsden Fm.	limestone, sandstone
Mississippian	Big Snowy Gp.	limestone, shale, sandstone
	*Madison Gp.	
	Sun River Dolo.	dolomite
	Mission Canyon Fm.	limestone
	Lodgepole Limestone	limestone
Devonian	Three Forks Fm.-Exshaw Fm.-Sappington Fm.	shale, limestone
	#Jefferson Fm.	limestone
	Maywood Fm.	shale
	Beartooth Butte Fm.	shale
Ordovician	Bighorn Dolo.	dolomite
Cambrian	Red Lion-Snowy Range Fm.	limestone
	Devils Glen Dolo.-Hasmark Dolo.	dolomite
	Damnation Ls.-Fishtrap Dolo.- --Wolsey Sh.	limestone, dolomite, shale
	Gordon Sh.-Silver Hill Fm.	shale
	Flathead Ss.	sandstone
Proterozoic (middle)	Belt Supergroup	argillite, shale, limestone

* Currently producing # Potentially productive

P-580, SNAKE RIVER BASIN

The Snake River downwarp is an arcuate basin whose borders lie on either side of the Snake River and roughly parallel the river. The basin lies between the overthrust fold belts of east-central and southeast Idaho and extends to the southwestern edge of Idaho, as far as, but not including, the Hells Canyon area.

The rock section is composed of numerous extrusive volcanic flows and air-fall material interbedded with fluvial and lacustrine clastic deposits which are more prominent in the southwestern area. Some black shales and a few coal beds are included in the section.

Numerous gas shows, ranging in quality from 750 to 1,400 Btu's per cubic foot have been found through seeps and in wells. Juvenile bitumens, apparently in place, have also been noted. Reservoir rocks and apparent source rocks have been identified. Trapping mechanisms pose a question. Drilling has been sparse to date and no commercial discoveries have been made, but there is continued industry interest spurred by shows. The potential for commercial natural gas accumulations is difficult to define. The exploration risk is high, but there are enough favorable indicators to hold out promise for the basin.

P-590, WYOMING-UTAH-IDAHO THRUST BELT

This area is made up of severely deformed Paleozoic and Mesozoic sediments, mostly of marine origin. Deformation occurred during the Laramide Orogeny in Cretaceous and early Tertiary time. The region is composed of a complex series of thrust sheets with anastomosing smaller thrust and later normal faults, making exploration difficult. Styles of deformation vary through the belt. In most areas the sediments are tightly folded as well as faulted. In other areas, Paleozoic rocks are severely faulted, whereas overlying Mesozoic sediments are both folded and faulted. The stacked sediment package is over 49,000 feet thick in the western portion of the province and 14,000 feet thick in the east. Production is presently confined to Wyoming and the area of Utah adjacent to the southwestern corner of Wyoming (Fossil basin). Oil, associated/dissolved gas, non-associated gas and condensate are produced. Non-associated gas from Paleozoic carbonate reservoirs is sour. The Idaho portion of the province has produced shows and continues to be an exploration target.

Reservoir rocks. Sixteen units ranging in age from Ordovician to Late Cretaceous are presently producing in this province. The Mississippian Madison Limestone, Triassic-Jurassic Nugget Sandstone and Permian-Pennsylvanian Weber Sandstone and Ordovician Bighorn Dolomite are major targets in this region. Other reservoirs include the Upper Cretaceous Frontier Formation; Jurassic Stump Sandstone and Twin Creek Limestone; Triassic Thaynes Limestone, Woodside Formation and Dinwoody Formation; Permian Phosphoria Formation; and Devonian Darby Formation.

Traps. Structural trapping affects all stratigraphic intervals and includes folded and thrusted anticlines. Potential stratigraphic traps include carbonate mounds in the Thaynes Limestone, changes in carbonate facies, and pinchouts in Upper and Lower Cretaceous sandstones.

Potential source rocks. The main source of hydrocarbons is Cretaceous marine shales. Other possible sources include the Phosphoria, Thaynes, and Devonian Three Forks Formations.

P-590, WYOMING-UTAH-IDAHO THRUST BELT
Generalized Stratigraphic Section

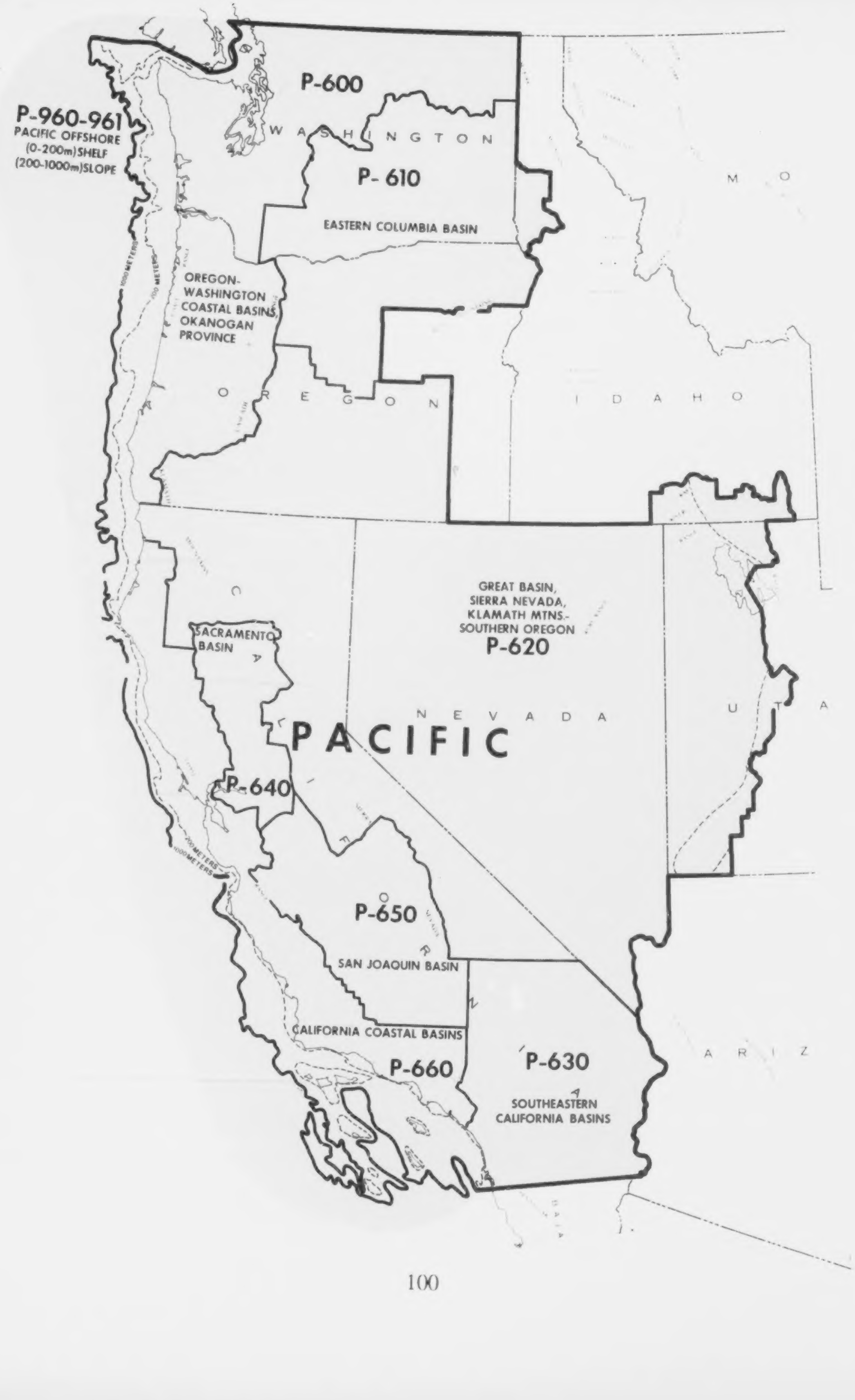
AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Eocene-Pliocene	Fowkes Fm.	shale, sandstone
Eocene	Green River Fm.	shale
	Wasatch Fm.	shale, sandstone
Late Cretaceous-Paleocene	Evanston Fm.	sandstone, coal
Mesozoic		
Cretaceous		
Late	Adaville Fm.	sandstone, shale, coal
	Hilliard Fm.-Shurtliff Ss.	shale, sandstone
	Frontier Fm.	shale, sandstone, coal
Early	Aspen Sh.	shale, sandstone
	*Bear River Fm.	shale, sandstone
	Gannett Gp.	shale, ss., cgl., ls
Jurassic	*Stump Ss.-Preuss Ss.	sandstone, evaporites, shale
	*Twin Creek Ls.	limestone
	Gypsum Springs Mbr.	shale, evaporites
Triassic-Jurassic	*Nugget Ss.	sandstone
Triassic	*Ankareh Fm.	shale, limestone, sandstone
	*Thaynes Ls.	limestone
	Woodside Fm.	shale, marl
	*Dinwoody Fm.	shale, limestone
Paleozoic		
Permian	*Phosphoria Fm.	shale, limestone
Pennsylvanian	*Wells Fm.-Weber Fm.	sandstone, limestone
	*Morgan Fm. (Amsden)	limestone, sandstone, shale
Mississippian	Brazer–Madison Gp.	limestone
	*Mission Canyon Ls. Mbr.	limestone
	*Lodgepole Ls. Mbr.	limestone
Devonian	*Darby Fm.-Three Forks Sh.--Jefferson Ls.	dolomite, shale, limestone, sandstone
Silurian		
Ordovician	*Bighorn Dolo.-Leigh Dolo.	dolomite, limestone
Cambrian	Gallatin Ls.	limestone, shale, dolomite
	Gros Ventre Fm.	shale, sandstone, limestone
	Flathead Ss.	sandstone

* Currently producing

Table 15. Estimated resources of natural gas for provinces of the Rocky Mountain Area, December, 1986 (billion cubic feet)

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPECULATIVE		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-500, Williston basin	0-15,000'		1,500	1,000	300	600	500	500	500	300	*
	15-30,000'								100	20	*
P-510, Powder River basin	0-15,000'		1,600	1,200	700	2,700	2,200	1,500	700	500	300
	15-30,000'								2,000	1,000	500
P-515, Big Horn basin	0-15,000'		1,000	550	400	1,000	550	400	2,000	1,600	200
	15-30,000'		430	125	100	1,300	650	500	3,000	2,000	400
P-520, Wind River basin	0-15,000'		1,600	1,200	600	3,900	2,600	1,300	*	*	*
	15-30,000'		2,400	1,800	1,300	2,900	1,100	500	700	400	*
P-530, Greater Green	0-15,000'		10,015	7,737	6,078	14,306	8,562	4,301	3,559	2,362	270
River basin	15-30,000'		2,245	1,579	1,014	27,324	20,981	14,281	6,402	1,184	620
P-535, Denver basin, Chadron	0-15,000'		4,900	2,900	1,800	4,200	2,000	1,000	1,200	500	200
arch and Las Animas arch	15-30,000'								*	*	*
P-540, Uinta/Piceance basins,	0-15,000'		8,200	5,700	4,000	3,900	2,300	1,200	2,300	400	200
Park and Eagle basins	15-30,000'		1,500	500	200	800	200	100	2,100	300	100
P-545, San Juan Mountains,	0-15,000'					1,000	400	100	1,400	700	*
San Luis/Raton basins, etc.	15-30,000'								600	300	*
P-550, Paradox basin	0-15,000'		200	130	50	3,000	900	500	700	300	100
	15-30,000'								*	*	*
P-555, San Juan basin	0-15,000'		3,000	2,500	2,000	4,000	3,500	3,000	*	*	*
	15-30,000'								*	*	*
P-560, Southern Basin	0-15,000'					5,600	1,400	*	100	50	*
and Range province	15-30,000'								*	*	*
P-565, Plateau province,	0-15,000'		40	20	10	80	40	20	500	250	40
Black Mesa basin	15-30,000'								*	*	*
P-570, Sweetgrass arch	0-15,000'		3,200	2,300	1,600	2,400	1,900	1,400	1,400	1,100	800
	15-30,000'								*	*	*
P-575, Montana Folded Belt	0-15,000'		100	10	5	2,000	1,000	*	3,500	2,500	*
	15-30,000'								*	*	*
P-580, Snake River basin	0-15,000'								300	200	100
	15-30,000'								*	*	*
P-590, Wyoming-Utah-Idaho	0-15,000'		3,400	2,300	1,000	2,500	1,500	300	15,000	7,000	2,500
Thrust Belt	15-30,000'		8,000	5,000	3,000	1,900	1,000	500	6,000	2,500	1,000
TOTAL, onshore	0-15,000'			27,547			29,352			17,762	
TOTAL, onshore	15-30,000'			9,004			23,931			7,704	
TOTAL, onshore, all depths				36,551			53,283			25,466	
GRAND TOTAL FOR AREA				36,551			53,283			25,466	

*Negligible quantity of natural gas estimated


P-600
P-960-961
PACIFIC OFFSHORE
(0-200m) SHELF
(200-1000m) SLOPE
WASHINGTON
P-610
EASTERN COLUMBIA BASIN
MO
1000 METERS
200 METERS
OREGON-
WASHINGTON
COASTAL BASINS,
OKANOGAN
PROVINCE
OREGON
IDAHO
GREAT BASIN,
SIERRA NEVADA,
KLAMATH MTNS.-
SOUTHERN OREGON
P-620
SACRAMENTO
BASIN
CALIFORNIA
NEVADA
PACIFIC
UTA
P-640
200 METERS
1000 METERS
P-650
SAN JOAQUIN BASIN
CALIFORNIA COASTAL BASINS
P-660
P-630
SOUTHEASTERN
CALIFORNIA BASINS
ARIZ
BAJA

PACIFIC AREA

During the past two years, exploration activity within the San Joaquin Valley has continued at low levels. One field of apparent significant size was discovered in the southern end of the basin. The field has been designated as the Landslide Field. Drilling activity continues along three major trends in the San Joaquin Valley:

1. The Stevens sands along the Bakersfield arch.
2. The Temblor Formation surrounding the Tulare Lake field discovery.
3. Field extensions along the western San Joaquin Valley.

The strongest exploratory pace continues along the Bakersfield arch in central Kern County, yielding many small extensions. In the northern San Joaquin Valley, exploration persists around the 1982 discovery of the Tulare Lake field. Two new oil fields and one new pool have been discovered within the past two years. Extensions of existing west side San Joaquin fields have played a significant role in reserve additions. One new field and many new oil pools have been discovered. Other significant activity comes from Mountain View/Edison field areas in the southeastern San Joaquin Valley.

There was a decrease in the estimates for potential natural gas resources in all categories for the San Joaquin Valley. This is the result of a continuing re-evaluation by the Pacific Area Committee. Gas production in the Valley is predominantly associated/dissolved gas and the estimate of the potential gas resources has been brought into line with the potential oil discoveries.

In the Sacramento Valley the estimates for Possible resources have been slightly decreased to account for developments and discoveries during the past two years. In the absence of significant, deeper exploration, there is no basis for changing the estimate for Speculative resources.

Significant exploration developments in the Sacramento Valley for 1985-86 include:

1. There was an 8% decline in drilling in 1985 followed by a 35% decline in 1986 - values which represent less decline than the average for domestic drilling. The basin is now the most active area for exploration and development in California.

2. There was greater emphasis on infill drilling and extensions to existing fields and significantly less wildcat exploration.

3. There was extensive development of F Zone fields throughout the northern portion of the valley including two new field discoveries and several major extensions that could be rated as "field size." Exploration for these erratic F Zone stratigraphic accumulations has been aided by improved seismic techniques.

4. Continued successful development of the Denverton field and the discovery of six small new fields highlighted activity in the southern Sacramento Valley.

The Coastal Basins have suffered probably the greatest decline in activity of any area in California. As a result, nothing of significance has been found that will alter the resource estimates.

Drilling and seismic activity has been at a low level in Oregon. Some extensions have been completed to Mist Gas Field which remains the only producing field in the state.

Washington has seen very little activity in the last two years. Acreage is being leased in the central part of the state preparatory to the drilling of another deep test.

Exploratory drilling in the Pacific Offshore has been rather limited and basically unsuccessful in the 1985-86 period. Drilling has begun from new platforms set to develop Point Arguello and Point Pedernales fields and plans are moving forward for development of Rocky Point field, all in the offshore Santa Maria basin.

P-600, OREGON-WASHINGTON COASTAL BASINS, OKANOGAN PROVINCE

This province presently has one productive field, Mist Field in Clatsop County, Oregon. Potential in the region is basically confined to the coastal region. The coastal region is composed largely of Tertiary rocks (both marine and continental) with some interbedded lava flows and is covered in places with glacial drift.

The Olympic Mountains are mostly a metamorphic complex with some lava flows. The Okanogan Highlands of northern Washington are a combination of intrusive and extrusive igneous rocks with metamorphosed regions. Historically there have been two other fields in the province: Ocean City and Bellingham. Ocean City in Grays Harbor County, Washington, produced approximately 12,500 barrels in four years from a fractured Oligocene sandstone The Bellingham gas field in Whatcom County, Washington, produced local amounts of Tertiary gas from sandstone lenses in glacial sediments.

Reservoir rocks. Present production is from the Eocene Cowlitz Formation. Potential reservoir rocks are the Miocene-Pliocene Quinault Formation, the Miocene Astoria Formation, the Miocene-Oligocene Yaquina Sandstone, and the Eocene Coaledo Formation.

Traps. The main traps in the area occur in sandstone lenses. Unconformity truncations affect Pliocene and late Eocene rocks. Shale diapirs with accompanying onlaps and faults form potential traps in Miocene and Pliocene rocks.

Source rocks. Potential source rocks in this area are the Miocene Nye Shale, the Oligocene Alsea Formation and the Eocene Coaledo and Yamhill Formations.

P-610, EASTERN COLUMBIA BASIN

This province has very little natural gas potential. Most of the region is covered with thick plateau basalts. The Cascade Mountains, a series of volcanoes, are also included in this region. Historically there has been one gas field in this province, Rattlesnake Hills. Production was from vesicular basalts. The trap was a faulted anticline with thin shales acting as the seal. Total production was one billion cubic feet of gas. The source rock is unknown. There is some possibility of production from reservoir rocks and source rocks lying below the thinner portions of the lava flows.

P-620, GREAT BASIN, SIERRA NEVADA, KLAMATH MOUNTAINS AND SOUTHERN OREGON

This province has seen limited exploration activity in the last two years. The region contains a thick Paleozoic section with lesser amounts of Mesozoic and Tertiary rocks. The Great Basin is composed of numerous horst and graben blocks which are internally folded and faulted. This complicates the stratigraphy and makes exploration more difficult. Present hydrocarbon production is limited to five fields in Nevada, four of these in Railroad Valley. One of the wells in Railroad Valley has the highest rate of oil production of any well in the lower 48 states. There is also limited production in the Klamath Mountains. The province is a region of major mineral exploration also.

Reservoir rocks. Past production has been from freshwater limestones and tuffs of the Eocene Sheep Pass Formation. Other potential reservoirs are the Permian Meade Park Shale Member of the Phosphoria Formation, the Mississippian Deseret Limestone and Chainman Shale and the Devonian Pilot Shale. Other Mesozoic and Paleozoic sandstones and carbonate rocks may be potential reservoirs.

Traps. Stratigraphic traps, including sandstone lenses and changes in carbonate facies, are probable traps in this area. Folds and faults are very likely traps. Combination traps may be most important.

Source rocks. Potential source rocks include the Tertiary Elko Formation and Sheep Pass Formation; the Upper Cretaceous Newark Canyon Formation; the Permian Meade Park Shale Member of the Phosphoria Formation; the Mississippian Deseret Limestone; and Chainman Shale; the Devonian Pilot Shale and Woodruff Formation; and the Ordovician Vinini Formation. Source rocks are moderately mature to severely altered in the province. Other shales and carbonate rocks may be potential source rocks in the area.

P-630, SOUTHEASTERN CALIFORNIA BASINS

This province includes the Mojave Desert, Salton Trough and Peninsular Ranges. Little is known about this nonproductive province. Marine Tertiary rocks are potential targets near San Diego adjacent to the San Andres fault and along the Colorado River. The region has limited hydrocarbon potential.

P-640, SACRAMENTO BASIN

The Sacramento basin is the northern portion of California's Great Valley. It is bounded on the east by the Sierra Nevada Mountains, on the northeast by the Cascade Mountains, on the north by the Klamath Mountains and on the west by the Coastal Ranges. It is separated from the San Joaquin basin by the Stockton arch. The Sacramento basin is a structural and stratigraphic basin about 200 miles long and 70 miles wide. Over 30,000 feet of sediments were deposited in the deepest portion of the basin. These rocks are Upper Cretaceous and younger in age. Much of the basin is veneered with Holocene and Pleistocene alluvial deposits. This is an important natural gas province; most of it is non-associated gas.

Although more than 8,000 wells have been drilled in the Sacramento basin, only a relatively small number have made significant penetration beneath the base of the Upper Cretaceous F Zone or below 11,000 feet. These relatively unexplored deeper portions of the basin are considered less attractive because of the generally poor reservoir quality of the rocks and super pressures with hydrostatic gradients in excess of 0.7 psi/foot in many areas. The testing of these deeper formations and portions of the basin has not been adequate to condemn them as exploration objectives.

Reservoir rocks. The producing horizons in this province are Upper Cretaceous to Eocene in age. All are sandstones and include the Eocene Domenigine Sandstone and Capay Formation; the Paleocene Meganos and Martinez Formations and the Upper Cretaceous Starkey, Winters, Kione and Forbes Formations.

Traps. In this province, most gas accumulations are found in structural/stratigraphic trap combinations. Anticlines and faulted anticlines are very important. Most sandstones are either lenticular in nature or are submarine canyon deposits. Truncations and onlapping occur.

Source rocks. Numerous organic-rich shales were deposited with and between the sandstone units. Potential source rocks include the Starkey, Winters, Kione and Forbes Formations. Many Paleocene and Eocene shales may also be source rocks.

P-650, SAN JOAQUIN BASIN

The San Joaquin basin occupies the southern portion of California's Great Valley. It is an asymmetrical structural and stratigraphic basin with its axis in the western part of the valley and is approximately 250 miles long and 50 to 60 miles wide. It is bounded on the east by the Sierra Nevada Mountains, on the south by the Tehachapi Mountains, on the west by the Coast Ranges and on the north by the Stockton arch. More than 31,000 feet of Cretaceous and younger sediments were deposited in this basin. Most of this is marine shales and sandstones, though continental deposits occur in younger intervals. The eastern portion of the basin is gently folded and faulted. The western portion is highly folded and thrust faulted. Sediments were deposited from both eastern and western sources,

P-640, SACRAMENTO BASIN
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Holocene		
Pliocene	*Tehama Formation	sandstone, shale
Miocene-Pliocene	Sycamore Formation	sandstone, shale, volcanics
Miocene	San Pablo Group	sandstone, shale
	Monterey Group	shale, sandstone
	Claremont Shale	shale
	Sobrante Sandstone	sandstone
Oligocene	Kirker Formation	volcanics, shale, sandstone
Eocene	*Markley Formation	sandstone, shale
	*Nortonville Shale	shale, sandstone
	*Domengine Formation	sandstone, shale
	*Capay Formation	shale, sandstone
Paleocene	*Martinez Formation	sandstone, shale
Mesozoic		
Cretaceous		
Late	Deer Valley Formation	sandstone, shale
	*Starkey Sandstone	sandstone
	Sawtooth Shale	shale, sandstone
	*Winters Sandstone	sandstone
	*Lathrop Sandstone	sandstone
	*Sacramento Shale	shale
	*Kione Sandstone–Forbes Shale	sandstone, shale
	*Guinda Sandstone	sandstone
	Funks Shale	shale
	#Sites Sandstone	sandstone
	Yolo Shale	shale
	#Venado Sandstone	sandstone
Early	Budden Canyon Fm.	sandstone, shale
L. Jurassic-E. Cret.	Stony Creek Formation	shale
Jurassic (?)	Franciscan Series	sedimentary and meta. rocks

* Currently producing # Potentially productive

resulting in different stratigraphy for the eastern and western portions of the province.

The San Joaquin basin is an important hydrocarbon province. The southern part of the basin mainly produces oil and associated/dissolved gas. Nearly all of this production is from Miocene and younger rocks. The northern part of the basin is an area of mostly non-associated natural gas production.

The flanks of the San Joaquin basin have been tested by thousands of wells. Most of these wells are shallow (less than 5,000 feet). Many wells in the basin have been drilled to depths between 10-15,000 feet along the basin margin and within the central basin. Depths greater than 15,000 feet have been tested only rarely. However, no significant encouragement at depths below 15,000 feet in the San Joaquin basin has been seen to date.

The Probable resources are likely to be found in field extensions and infill drilling. Possible resources are expected to be found in associated gas fields ranging in size from 0.25 to 100 Bcf. Most fields

P-650, SAN JOAQUIN BASIN
Generalized Stratigraphic Section

AGE	FORMATION AND LITHOLOGY		
	North	West	East
Cenozoic			
Pleistocene	*Tulare Fm.–ss, sh	*Tulare Fm.–ss, sh	
Pliocene	*San Joaquin Fm.–ss, sh	*San Joaquin Fm.–ss, sh	Kern River Fm.–ss, sh
Miocene-Pliocene	*Etchegoin Fm.–ss	*Etchegoin Fm.–ss	Chanac Fm.–ss, sh
	Reef Ridge Sh.–sh	Reef Ridge Sh.–sh	
Miocene	*McLure Sh.–sh, ss	*Monterey Fm.–sh, ss	*Santa Margarita Ss.–ss
			Fruitvale Sh.–sh
	*Temblor Fm.–ss, sh		*Temblor Fm.–sh,ss,slt
		*Temblor Fm.–ss, sh	*Olcese Ss.–ss
			*Freeman Jewett Slts. sh,silt,ss
	*Burbank Sand–ss		*Vedder Sand–ss
Oligocene	Wherley Sh.–sh		
	*Vaqueros Ss.–ss		*Walker Fm.–ss,sh
	Tumey Fm.–sh	Tumey Fm.–sh	
	*Kreyenhagen Sh.–sh	*Kreyenhagen Sh.–sh	
	*Adams Ss.–ss	*Lodo Fm.–ss, sh	
	Arroyo Hondo Fm.–sh		
Paleocene	*"Martinez" Fm.–ss		
Late Cretaceous-Paleocene	*Moreno Fm.–ss, sh		
Mesozoic			
Late Cretaceous-Early Cretaceous	*Panoche Gp.–ss, sh		
Early Cretaceous	Fresno Springs Canyon Sh.–sh		
	Gravelley Flat Fm.–ss, sh		
	Wisenor Fm.–ss, sh		
Late Jurassic (?)	Franciscan rocks–ss, sh, chert, ls, schist		

* Currently producing

will average 1 to 12 Bcf of gas. Speculative resources are expected to be found in associated gas fields ranging in size from 10 to 150 Bcf with the average ranging from 10 to 20 Bcf.

Reservoir rocks. Nearly all reservoir rocks in the basin are sandstones. These range in age from Upper Cretaceous to Pleistocene. Included are the Upper Cretaceous to Tertiary Moreno Formation and numerous Tertiary and Pleistocene units. Some production is from Miocene fractured shales and from fractured basement schists.

Traps. All producing fields in the basin involve more than one trapping style. Anticlines and faulted anticlines are common and may be combined with one or more stratigraphic mechanisms. Common stratigraphic traps include sandstone pinchouts, truncations and diagenetically altered permeability.

Source rocks. Most of the shales in the basin are sapropelic. All are mature and are probable source rocks.

Trends. Producing trends in the province are the Bakersfield arch, West Side, East Side, Central Valley, South End Overthrust area, Paloma Deep production and the Northern Gas Province.

P-660, CALIFORNIA COASTAL BASINS

This province is made up of the Coast Ranges, Transverse Ranges and six small basins. Large quantities of oil, associated/dissolved and non-associated gas are produced in this province. Most production occurs in the southern basins.

The Los Angeles basin is a triangular region about 70 miles long and 40 miles wide and extends offshore. It covers approximately 1,450 square miles and is bounded on the north by the San Gabriel Mountains, on the southeast by the Santa Ana Mountains and on the south by other parts of the Peninsular Ranges. More than 31,000 feet of Miocene and younger sediments fill the deeper parts of the basin. Most of the basin is covered by Pleistocene alluvial deposits. Basin deformation began in the Miocene and culminated in the mid-Pleistocene. Major faults and folds trend northwesterly across the basin.

The Ventura basin is a long eastward-trending re-entrant. It is bounded by two of the Transverse Ranges. Most of this basin is offshore. Compressional forces have formed east-trending anticlines and thrust faults in the basin. As much as 55,000 feet of sediments were deposited within the onshore portion of this basin.

The Santa Maria basin is a wedge-shaped re-entrant in the Coast Ranges. Sedimentary rocks are confined to 30 miles onshore but extend offshore. East-trending elongate folds cross the region.

The Santa Cruz basin is a wedge-shaped coastal basin. It covers approximately 260 square miles. It is bounded on the north and east by the San Andreas fault and Franciscan basement rock outcrops and on the south by Monterey Bay.

The Salinas-Cuyama basin is an elongate, northwest-trending onshore basin. It is about 160 miles long and 28 miles wide and covers 3,100 square miles. It is bounded on the southwest by the Naciemento fault zone and on the northeast by the San Andreas fault zone. It contains more than 15,000 feet of Tertiary sedimentary rocks.

The Humboldt, or Eel River, basin is in northwestern California. It is triangular in shape and covers 575 square miles. It is bounded on the northeast and south by up-thrown basement rocks. It contains more than 12,000 feet of Miocene and younger rocks. Basin deformation occurred during the Pleistocene.

Reservoir rocks. The reservoir rocks in the Los Angeles basin are the Pliocene Pico and Repetto Formations; the Miocene Puente and Topango Formations and the fractured Jurassic Catalina Schist. Of these, the Repetto Formation is the most prolific. Reservoir rocks in the Ventura basin are the Pliocene Pico and Repetto Formations; the Miocene Rincon Claystone and Vaqueros Formation; the Eocene-Oligocene Sespe Formation and the Eocene Coldwater Sandstone. Of these, the Pliocene and Miocene are the most prolific. In the Santa Maria basin, the reservoir rocks are the Pliocene Foxen and Sisquoc Formations; the Miocene Monterey Formation; the Oligocene-Miocene Point Sal and Lopse Formations and the Jurassic Knoxville Formation. Much of the production in this basin is from fractured reservoirs in cherts, shales and tight sandstones. In the Salinas-Cuyama basin, the main reservoirs are the Miocene Dibble Sandstone and the Miocene Lombardi Sandstone. In the Santa Cruz basin, production is from Eocene sandstones. Probable reservoirs in the Humboldt basin are the Pliocene Scotia Bluff Sandstone, Rio Dell Formation and Eel River Formation and the Miocene Pullen Formation.

Traps. The major trapping mechanisms in the Los Angeles basin and Humboldt basin are anticlines, faults and faulted anticlines. These are important trap formers in the other basins as well. Other trapping mechanisms include sandstone lenses, truncations and porosity variations in the Santa Maria basin. Sandstone pinchouts occur in all basins. Onlapping sandstones form traps in the Salinas-Cuyama basin. Fracture porosity is important in the Los Angeles, Santa Maria and Ventura basins.

Source rocks. The Miocene Monterey is a likely source rock in the Ventura, Santa Maria and Salinas-Cuyama basins. The Miocene Rincon Claystone is a probable source rock in the Ventura basin. In the Los Angeles basin, the source rocks are the Pliocene Repetto Formation and the Miocene Puenta and Modelo Formations. In the Humboldt basin, the probable source rocks are the Pliocene Rio Dell and Eel River Formations and the Miocene Pullen Formation.

P-660, CALIFORNIA COASTAL BASINS
Generalized Stratigraphic Section

AGE	FORMATION AND LITHOLOGY		
	Los Angeles basin	Ventura basin	Santa Maria basin
Cenozoic			
Pleistocene	San Pedro Fm.-- La Habra Fm.-ss, sh	San Pedro Fm.-- Saugus Fm.-ss, cong Santa Barbara Fm.-sh	Orcutt Fm.-ss Paso Robles Fm.-- Santa Barbara Fm.- shale sandstone
Plio-Pleist.	Fernando Fm.-- San Diego Fm.-ss, sh		
Pliocene		*Pico Fm.-- Sunshine Ranch Fm.-ss, sh	Careaga Ss.--Morales– *Foxen Muds.-sh, ss
	*Repetto Fm.-ss, sh		
Mio-Pliocene	Capistrano Fm.-- Olay Fm.-ss, sh	Ridge Basin Gp.-- Towsley Fm.-ss, sh, cong	*Sisquoc Fm.-silt, ss
Miocene	*Puenta Fm.-- Monterey Fm.-sh, ss "Santa Margarita"-ss San Onofre Breccia *Topanga Fm.-ss	Monterey--Castaic-- Mint Canyon-- *Modelo Fm.-ss,sh Topanga Fm.ss, cgl vol Tick Canyon Fm.-cong	Santa Margarita Fm.-- *Monterey Fm *Point Sal Fm.-sh, ss *Lopse Fm.-- *Rincon Sh.-sh
Olig.-Miocene	Vaqueros Fm.-ss	*Vaqueros Fm.-- Vasquez Fm.-sh, ss	Vaqueros Fm.-ss, sh
Oligocene			Simmler--Alegria-- Sespe Fm.-ss, cong, sh.
Olig.-Eocene	Sespe Fm.-ss, cong	*Sespe Fm.-ss, cong	
Eocene	Santiago Fm.-- Poway Gp.-- La Jolla Gp.-ss, sh, cong Matilija Fm.-ss	*Coldwater Ss.--ss Cozy Dell Sh.-- *Llajas Fm.-sh Matilija Fm.-ss Santa Susana Fm.-sh	Sacate Fm.--ss, sh Cozy Dell Sh.-sh
Paleo.-Eocene			Pattiway Fm.-- Anita Fm.-ss, sh
Paleocene	Silverado Fm.-ss, sh	"Martinez" Fm.-- Coal Canyon Fm.-ss,cong	
Mesozoic			
Cretaceous			
Late	Rosario Gp.--Williams-- Ladd--Lusardi Fm.- ss, cong, sh Trabuco Fm.-cong	Chatsworth Fm.-- Tuna Canyon Fm.-ss, sh	Jalama Fm.-sh, ss
Early	missing	missing	Espada Fm.-ss, sh *Knoxville Fm. and Franciscan rocks
Jurassic			

* Currently producing

P-960 AND P-961, PACIFIC OFFSHORE, SHELF AND SLOPE

Many of the coastal deposits extend offshore and are especially important in the southern California regions. The Los Angeles, Ventura and Santa Maria basins all extend offshore and all present offshore production is confined to these extensions. Offshore southern California is composed of numerous horsts and grabens, and as much as 58,000 feet of sediments lie in the offshore Ventura basin. The southern California region has good potential for future resource development. Although there is presently no production in offshore Washington or Oregon, the shelf is 30 to 40 miles wide and has potential for future development.

Reservoir rocks. Reservoir rocks in the California Offshore area include both sandstones and fractured shales. These range in age from Eocene to Pliocene. Included are the Eocene Sacate and Cozy Dell, the Oligocene Sespe, Alegria and Gaviota, the Miocene Vaqueros, Rincon, Monterey fractured shales and Puente and the Pliocene Repetto and Pico.

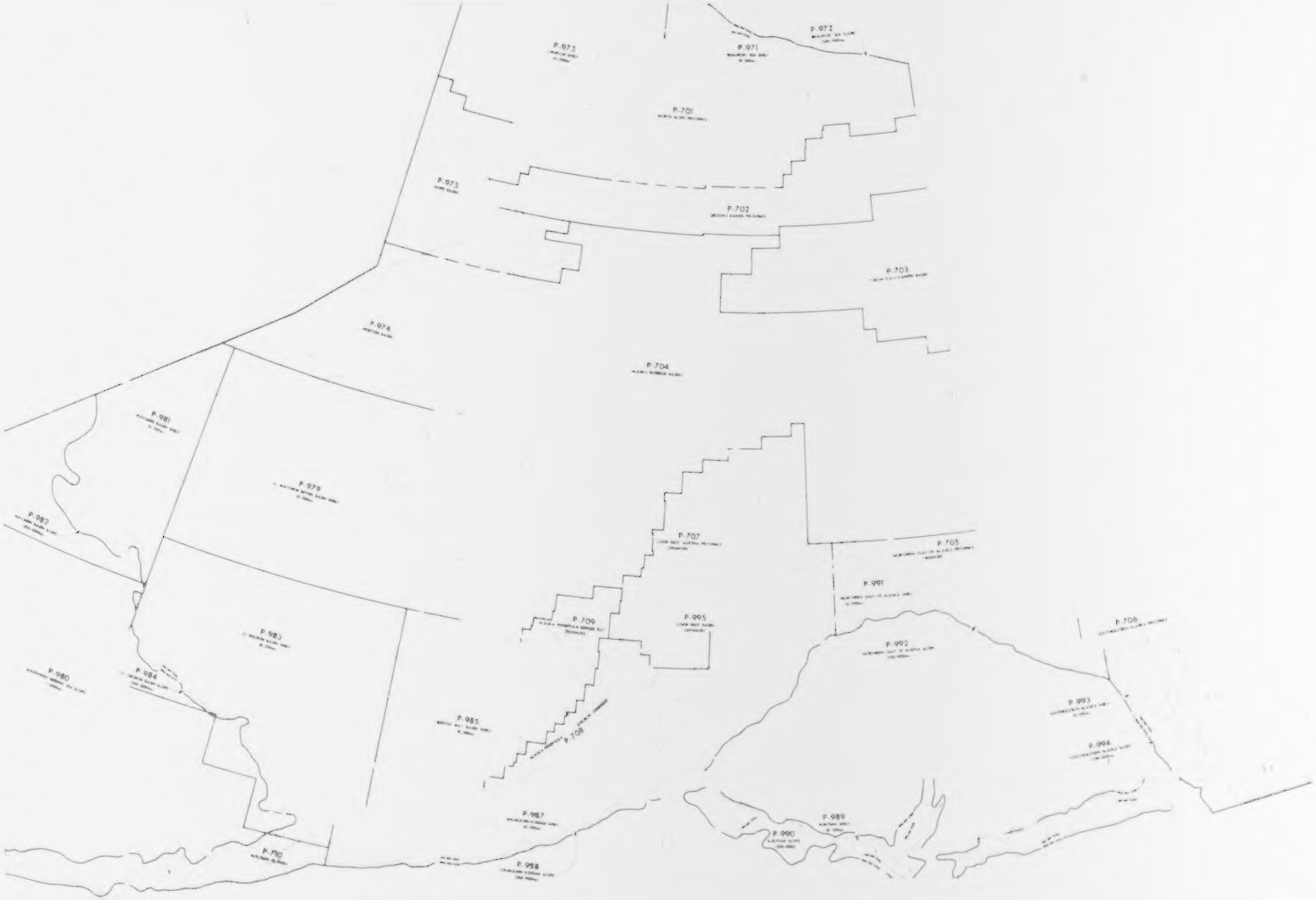
Traps. All producing fields involve faulted anticlines. Stratigraphic mechanisms such as truncations, sandstone pinchouts and diagenetically altered permeability also affect production.

Source rocks. Pliocene shales, the Miocene Monterey Formation and the Miocene Rincon Claystone are probable sources of most of the hydrocarbons.

Table 16. Estimated resources of natural gas for provinces of the Pacific Area, December 1986 (billion cubic feet)

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPEC.		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-600, Oregon-Washington	0-15,000'		20	15	10	2,000	1,000	300	5,000	1,700	*
coastal basins, Okanogan	15-30,000'								2,000	*	*
P-610, Eastern Columbia	0-15,000'								3,000	1,000	*
Basin	15-30,000'								2,000	*	*
P-620, Great Basin-	0-15,000'								2,000	700	*
Southern Oregon	15-30,000'								1,000	*	*
P-630, Southeastern	0-15,000'								1,000	500	*
California basins	15-30,000'								*	*	*
P-640, Sacramento	0-15,000'		1,100	600	300	3,300	1,600	700	5,000	1,500	*
basin	15-30,000'								*	*	*
P-650, San Joaquin	0-15,000'		500	250	150	1,000	750	500	500	*	*
basin	15-30,000'					1,000	550	*	1,500	500	*
P-660, California	0-15,000'		800	480	250	3,500	2,100	900	1,300	600	200
coastal basins	15-30,000'		300	200	200	1,200	600	400	800	400	100
P-960, Pacific shelf		0-200 m	110	65	50	7,575	4,735	2,840	7,745	3,661	880
P-961, Pacific slope		200-1,000 m	275	172	120	6,685	4,178	2,505	9,665	5,167	2,035
TOTAL, onshore	0-15,000'			1,345			5,450			6,000	
TOTAL, onshore	15-30,000'			200			1,150			900	
TOTAL, onshore, all depths				1,545			6,600			6,900	
TOTAL, offshore		0-200 m		65			4,735			3,661	
TOTAL, offshore		200-1,000 m		172			4,178			5,167	
TOTAL, offshore, all depths				237			8,913			8,828	
GRAND TOTAL FOR AREA				1,782			15,513			15,728	

*Negligible quantity of natural gas estimated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ALASKA AREA

With a total area of approximately 1.15 million square miles (about half of which is on land, the other half is between the shoreline and the -1,000-meter isobath), Alaska is a vast frontier. Oil production has been established on the North Slope and in the Cook Inlet area to the south (WSW of Anchorage). Natural gas production is currently restricted to the Cook Inlet area because of the lack of pipeline systems to bring North Slope gas to market.

Tectonically and stratigraphically, Alaska includes parts of the Rocky Mountain and Western North American Borderland settings. Producing, and prospectively productive, intervals are of Paleozoic age or younger. Geologic structures include both folds and faults. Reservoir lithologies range from sandstones to carbonate rocks.

The main emphasis of exploratory efforts for the past two years has been focused on the North Slope-Beaufort Sea and Bering Sea areas. The Beaufort Sea is still considered to have excellent hydrocarbon potential. During 1984 and 1985, Outer Continental Shelf (OCS) sales 83 (Navarin-Bering Sea) and 87 (Beaufort Sea) were held. The State of Alaska offered two lease sales on the North Slope and one in Cook Inlet. The Arctic National Wildlife Refuge remains the most promising untested onshore acreage in the United States, and whether or not it will be opened to oil and gas development will depend upon the decision of Congress.

The Cook Inlet basin has lacked major oil or gas discoveries for several years. Negative results have also come from the offshore OCS basin in the Gulf of Alaska and the Bering Sea OCS basins of Norton Sound, St. George and Navarin. Consequently, the estimates of Speculative gas resources for Alaska have been reduced by 19%. As a result, total gas resource estimates have declined by 13%.

P-701, ALASKA NORTH SLOPE

The Alaska North Slope geologic province includes a total of 54,610 square miles and extends from the Beaufort Sea in the north to the Brooks Range in the south. The majority of Alaska's oil production currently comes from this area and is concentrated along the Barrow arch trend. The province also contains large reserves of natural gas (currently more than 31 Tcf proven), but there is no current gas production due to lack of pipeline facilities and a poor economic climate.

Reservoir rocks. Deposition along the Barrow arch took place in a linear, downfaulted basin located along a stable, passive cratonic margin. Potential reservoir rocks consist largely of Mississippian to Tertiary clastic rocks deposited in this basin. Current production comes from the Ellesmerian sequence of rocks, ranging in age from Mississipian to earliest Cretaceous, and from the Brookian sequence, ranging in age from Early Cretaceous to Tertiary. Principal sandstone reservoirs include the Permo-Triassic Sadlerochit Group (oil and gas), Triassic Sag River Formation (oil and gas), Early Cretaceous Kuparuk River Formation (oil and gas), sandstones of the Early Cretaceous Nanushuk Group (oil and gas), sandstones of the Late Cretaceous Colville Group (oil), Late Cretaceous West Sak sands (oil), and Tertiary Sagavanirktok Formation (gas). Carbonate reservoirs include the Mississippian-Pennsylvanian Lisburne Group (oil) and the Triassic Shublik Formation (oil and gas).

Traps. Accumulations in the Ellesmerian sequence are trapped by combinations of folding, faulting, and truncation by a major unconformity at the base of the Brookian sequence (Lower Cretaceous unconformity). Seals are generally provided by overlying shales or other less permeable rocks. Brookian sequence hydrocarbon accumulations appear to be due primarily to stratigraphic changes. Permafrost is believed to be a trapping mechanism for gas accumulations in the younger Brookian sequence.

Potential source rocks. Shales contained in Mississippian, Permian, Jurassic, Cretaceous and Tertiary sequences are the most likely source rocks for the hydrocarbon accumulations.

Future exploration. Based on the successful exploration efforts to date, the main exploratory interest in Alaska remains in the North Slope province and the adjacent Beaufort Sea province.

P-702, ALASKA SOUTHERN FOOTHILLS AND BROOKS RANGE

This province encompasses the Brooks Range from the foothills in the north to the Koyukuk, Yukon Flats and Kandik basins which form the southern border. The area of the entire province totals 65,373 square miles. Tectonically the province has been classified as a deformed cratonic margin which has been associated with strong folding and overthrusting.

P-701, ALASKA NORTH SLOPE
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Quaternary	Gubik Formation	gravels, sands, silts, clays
Tertiary	Brookian sequence	
	*Sagavanirktok Formation	gravels, sands, silts, clays
	*Flaxman Island sands	
	*Ugnu Formation/*Point Thomson sands	
Mesozoic		
Late Cretaceous	Colville Group	
	Prince Crk. Fm.	shale, sandstone
	*West Sak sands	sandstones
	Seabee Fm.	shale
Early Cretaceous	*Nanushuk Group/unnamed shale	sandstone, conglomerate,shale
	Okpikruak Fm.	conglomerate, shale
	*Ellesmerian sequence	
	*Kuparuk R. Fm./*Kemik Ss.	sandstone
Jurassic	*Kingak Shale	shale, sandstone
Triassic	*Karen Crk. Ss./*Sag River Fm.	sandstone, conglomerate
	*Shublik Formation	carbonate
	*Sadlerochit Group (Ivishak Ss.)	sandstone, conglomerate, shale
Paleozoic		
Permian		
Pennsylvanian	*Lisburne Group	carbonates
Mississippian	*Endicott Group (Kekiktuk Formation)	sandstone, conglomerate
Pre-Mississippian		basement complex

*Currently producing

No oil or gas fields or producing trends have been established in this province to date. However, the occurrence of bitumen, solid hydrocarbons and oil shale (Tasmanite) of Early Cretaceous age have been reported.

Reservoir rocks. Potential reservoir rocks range from Devonian reef carbonates of the Hunt Fork-Beaucoup Formation to the Cretaceous Torok Shale. Other potential reservoir rocks are included in the Endicott Group (Devonian-Mississippian), the Skajit Formation (Devonian-Silurian), Lisburne Group (Mississippian-Pennsylvanian), Shublik Formation (Triassic), and Fortress Mountain Formation (Early Cretaceous).

Traps. Prospective traps are considered to be related to thrust faults and faulted anticlines.

Potential source rocks. Shales and carbonate rocks, ranging in age from Devonian to Cretaceous are considered to be potential sources of hydrocarbons. These formations include Kayak Shale (Mississippian), "Kavik" Formation (Mississippian), Kingak Shale (Jurassic), and "pebble shale" (Early Cretaceous).

P-703, YUKON FLATS BASIN AND KANDIK BASIN

This province includes a surface area of over 30,000 square miles and is divided into the Kandik basin and the Yukon Flats basin. Both basins are considered intermontane with sedimentary section possibly exceeding 20,000 feet. The one exploratory well in the Kandik basin encountered tectonically repeated overly mature Mesozoic rocks. The two exploratory wells in the Yukon Flats basin were drilled in the extreme northeast margin and encountered thermally mature Paleozoic rocks at total depth. Although only three wells have been drilled in this province, the prospect for gas production appears small.

P-704, ALASKA INTERIOR BASINS

This province stretches over nearly 260,000 square miles from the southern foothills of the Brooks Range in the north to the Alaska Range and the Chugach Mountains in the south. It is bordered on the west by the Bering Sea and on the east by the Canadian border. Several sedimentary basins are included in the province: Bethel basin, Inoko basin, Lower Tanana basin, Holitna basin, Yukon delta (onshore portion of Norton basin), Minchumina basin, Middle Tanana basin and Copper River basin. No production of oil or gas has been established in this province. However, the Bethel basin, Copper River basin, Minchumina basin, and Holitna basin are thought to have some potential for future natural gas production.

The southeastern basins generally contain Tertiary rocks overlying Precambrian basement. Generally, the shallow intermontane Minchumina and Middle Tanana basins contain non-marine molasse sediments which are thermally immature. Apart from coaly and carbonaceous material, the organic carbon content is low.

The northwestern portion of the province includes a thin Tertiary section which is probably thermally mature but contains a low organic carbon content. The Cretaceous section is thermally overmature. No shows have been reported in wells drilled to date.

The Copper River basin is a topographic basin floored with unconsolidated deposits of Quaternary age. In at least two localities in the south-central part of the basin, flammable methane gas associated with saline springs seeps through the Quaternary sediments. Mesozoic sediments crop out along the periphery of the basin. Exposures indicate a thick section of both Upper and Lower Cretaceous rocks underlain by a thinner sequence of Jurassic rocks, which in turn are underlain by a series of Upper Triassic sedimentary rocks. Both the Jurassic and Cretaceous rocks are of marine origin and contain potential source rocks, in the form of organic shales, and potential reservoir sandstones. Triassic carbonates are also considered to be potential reservoirs. Wells drilled to date in the Copper River basin have encountered minor gas shows.

P-705, NORTHERN GULF OF ALASKA (ONSHORE)

This province encompasses approximately 15,000 square miles. It is bordered on the north by the Chugach Mountains, on the south by the Gulf of Alaska and on the east by the Canadian border. The major tectonic elements include the Yakataga and Yakatat basins. Nearly all rocks are of Tertiary age and consist almost entirely of detrital units. Prospective reservoir rocks range in age from Eocene to Miocene.

Oil production has occurred in the Katalla trend, on the shore of the Gulf of Alaska east of Cordova, which is the only established production in southern Alaska outside of the Cook Inlet area. Oil and gas seeps were discovered in the Katalla area about 1896 and the first successful well was drilled in 1902. A small refinery was built in 1911, but it burned down in 1933 and there has been no production at Katalla since then. About 36 wells were drilled, all comparatively shallow, from 550 to 750 feet in depth. Total oil produced from the field was about 154,000 barrels. Later onshore exploratory wells in the province have encountered minor oil and gas shows.

P-706, SOUTHEASTERN ALASKA

This province is bordered on the north, south and east by the Canadian border and by the Pacific Ocean on the west. It covers a total area of about 31,000 square miles. No oil or gas production has been established in the province to date. Most rocks in the province have undergone intense deformation so that it is difficult to assess their petroleum potential, if any. Predominantly they consist of metamorphic and crystalline rocks.

P-707, COOK INLET—SUSITNA PROVINCE (ONSHORE)

This province encompasses a total area of 45,568 square miles. The province is bounded on the north and west by the Alaska Range and by the Chugach and Cook Inlet in the south. The major tectonic elements include the Susitna basin, Matanuska Valley, Cook Inlet basin and Augustine-Sedovia arch. Producing trends established to date are the Sterling/Beluga trend and the Hemlock/Tyonek/West Foreland trend. A few oil and gas seeps, as well as subsurface shows, have been reported. Several gas fields and two oil fields are on production from this province.

Reservoir rocks. All prospective intervals consist of detrital rocks, mainly sandstones, and mainly of Tertiary age.

Traps. Both structural and stratigraphic traps occur at all reservoir levels. All production thus far is from anticlines and faulted anticlines. Caprocks include the Kenai Group siltstone (Oligocene-Pliocene) and the siltstone unit of the West Foreland Formation (Paleocene).

Potential source rocks. The Tertiary Kenai Group shales and claystones are considered to be potential source rocks for gas. The mid-Jurassic Naknek Formation is considered capable of generating both oil and gas.

P-708, ALASKA PENINSULA—SHELIKOF PROVINCE (ONSHORE)

This province encompasses a total area of 12,777 square miles. It is bordered on the north and west by the Aleutian Range and on the southeast by the Shelikof Strait. The major tectonic elements include the Wide Bay and Chignik anticlines and the Pearl Creek dome. The major stratigraphic units range in age from Triassic to Tertiary. Sandstone and conglomerate units form all reported potential reservoirs. No oil or gas production has been established in the province although several wells reported oil shows.

P-707, COOK INLET–SUSITNA PROVINCE (ONSHORE); P-995, COOK INLET BASIN-OFFSHORE
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Tertiary	Kenai Group	
	*Sterling Formation	sandstone and siltstone
	*Beluga River Formation	congl., sandstone, siltstone, and claystone
	*Tyonek Formation	congl., sandstone, siltstone, claystone, coal
	*Hemlock Formation	congl., sandstone
	*West Foreland Formation	congl.,sandstone and claystone
	Chickaloon Formation	siltstone, sandstone, coal
Mesozoic		non-marine clastic rocks
Cretaceous	Kaguyak Formation	sandstone, shale
	Matanuska Formation	sandstone, shale
	unnamed	sandstone, shale
Jurassic	Naknek Formation	sandstone, shale
	Chinitna Formation	sandstone, shale
	Tuxedni Group	congl., sandstone, shale
	Red Glacier Formation	
	Talkeetna Formation	pyroclastics, volcaniclastics

*Currently producing

P-709, ALASKA PENINSULA—BRISTOL BAY (ONSHORE)

This province includes 22,187 square miles in southwestern Alaska. No production has been established, but potential for oil and both associated/dissolved and non-associated gas is envisaged. The region is bordered by the Aleutian Range on the southeast and by Bristol Bay on the northwest. Sedimentary rocks range in age from Jurassic to Pliocene and potential source and reservoir rocks exist throughout the section. Sandstones are the dominant lithology. A variety of structural and stratigraphic traps may exist. Wells drilled in the province have encountered minor oil and gas shows. A gas test well drilled in the Becharof area was abandoned as dry in 1985.

P-710, ALEUTIAN ISLANDS

This province includes the land area of the Aleutian Islands. It is located to the southwest of the Alaska Peninsula and encompasses a large number of mainly volcanic islands. The volcanic nature of the islands suggests negligible potential for natural gas.

P-971 AND P-972, BEAUFORT SEA SHELF AND SLOPE

These provinces cover a total area of approximately 40,000 square miles. The first commercial oil and gas field on the Beaufort Shelf is now being developed just north of the Sagavinirktok delta and just northeast of the Prudhoe Bay field. Three other discoveries north and west from the Kuparuk delta are judged to be subcommercial with currently depressed oil prices, but optimism remains that major oil and gas reserves will be produced from the Beaufort Shelf region. No estimate has been made for potential which might exist below the continental slope at water depths from 200-1,000 meters because this area lies below the polar ice pack.

Reservoir rocks. Potential reservoir rocks are similar to the section in the adjacent onshore areas of the North Slope. The stratigraphic section contains rocks which range in age from Mississippian to Tertiary and are dominantly clastic rocks with the exception of Mississippian carbonates. Most of the prospective reservoir rocks occur in the Permo-Triassic section, but there are also some prospects in the Tertiary section to the east.

Traps. Stratigraphic traps are believed to be abundant. They include pinchouts (in Tertiary and Cretaceous units), truncations (Jurassic and Triassic rocks), and onlap in the Mississippian sequence. Structural traps are also postulated related to both folding and faulting.

Potential source rocks. Potential source rocks for both oil and gas exist in the Mississippian to Early Cretaceous sequence and in Late Cretaceous-Tertiary rocks. The rocks range from thermally immature to very mature.

Future exploration. Most of the exploration plays to date consist of extensions of onshore trends. The difficulties of interpretation are exemplified by recent dry holes. The enormous potential of the adjacent onshore area and the likelihood of extensions of similar conditions into the offshore area are stimulants to continued exploration in spite of high costs and difficult conditions.

P-973, CHUKCHI SHELF

This province covers an area of approximately 61,000 square miles. No oil or gas production has been established to date. Potential reservoir rocks range in age from Mississippian to Tertiary. The rocks are predominantly clastic, although prospective reservoirs in Mississippian-age rocks are limestones and dolomites. Both stratigraphic and structural traps are anticipated. There has been no exploratory drilling to date in this province.

P-974, NORTON BASIN

This province covers an area of over 43,000 square miles. No oil or gas production has been established to date despite the drilling of 6 exploratory wells during 1984 and 1985. Prospective reservoir rocks range in age from Cretaceous to Tertiary and consist mainly of sandstones. Stratigraphic and structural traps are anticipated and have been noted in Tertiary rocks. Gas seeps, rich in carbon dioxide, have been reported from the area.

P-975, HOPE BASIN

This province is dominantly an offshore area, including mainly Kotzebue Sound and parts of the Bering Strait, but it also extends onshore to include a small area of the Seward Peninsula. Sedimentary rocks in the area range in age from Cretaceous to Tertiary. No natural gas or oil production has been established in the province.

The onshore portion is considered to have low potential for natural gas production. It contains a thin section of thermally immature, non-marine Tertiary sandstones, conglomerates and shales. The offshore portion has a thicker sedimentary section and is considered to have some potential from rocks of Cretaceous and Tertiary age. Both structural and stratigraphic traps may exist. Potential source rocks are primarily of Tertiary age.

P-979, ST. MATTHEW BASIN-BETHEL BASIN SHELF

This province includes an area of more than 91,000 square miles. No oil or natural gas production has been established, and the province is not considered to have potential for future natural gas production primarily due to a thin section of thermally immature rocks.

P-980, SOUTHWEST BERING SEA SLOPE

Water depths in this province are all greater than 1,000 meters. No estimate of natural gas potential has been made at this time.

P-981 AND P-982, NAVARIN BASIN, SHELF AND SLOPE

These provinces include an area of approximately 49,000 square miles covered by water depths of less than 1,000 meters. Sedimentary rocks range in age from Jurassic to Tertiary, and detrital units predominate. No production of natural gas or oil has been established in these provinces to date despite the drilling of 9 exploratory wells during 1985. Potential reservoir rocks are of Jurassic, Cretaceous and Tertiary age. Both stratigraphic and structural traps are believed to occur. Pinchouts generally occur in Tertiary strata, whereas truncations and onlap are associated with Mesozoic rocks. Anticlines and faulted anticlines are common in Mesozoic as well as Tertiary units. Growth faults and draping also occur in the Tertiary section. Potential source rocks probably exist in the Jurassic, Cretaceous and early Tertiary sections.

P-983 AND P-984, ST. GEORGE BASIN, SHELF AND SLOPE

These provinces encompass an area of approximately 96,000 square miles. No oil or gas production has been established to date despite the drilling of 9 exploratory wells during 1984 and 1985. Sedimentary rocks in the provinces are predominantly detrital and range in age from Jurassic to Tertiary. Potential reservoir rocks in the shelf province consist of sandstones of Jurassic, Cretaceous and Tertiary age. In the slope province, potential reservoirs for oil and gas are Paleogene (lower Tertiary) turbidites.

P-985, BRISTOL BAY BASIN SHELF

Approximately 55,000 square miles are included in this province which is all covered by water depths of less than 200 meters. Sedimentary rocks are generally detrital and range in age from Jurassic to Tertiary. No natural gas or oil production has been established to date. Potential reservoir rocks are sandstones of Jurassic, Cretaceous and Tertiary age. Both stratigraphic and structural traps occur. Truncations are most common in Mesozoic strata, whereas onlap and pinchouts appear to be restricted to Tertiary units. Faulted anticlines and faults are common at all stratigraphic levels. Potential source rocks are mostly of Cretaceous and early Tertiary age, although Jurassic units may also be a possible source.

P-987 AND P-988, SHUMAGIN-KODIAK SHELF AND SLOPE

This area lies offshore from southern and southwestern Alaska and encompasses an area of over 80,000 square miles. Sedimentary rocks are Cretaceous and younger, but Tertiary detrital units predominate. No natural gas or oil production has been established in the province. Potential for natural gas production is believed to occur in rocks of Tertiary age, generally sandstones, in the Shelf area. Traps may be either structural or stratigraphic. Most potential source rocks are in the Tertiary section.

P-989 AND P-990, ALEUTIAN SHELF AND SLOPE

The Aleutian Shelf and Slope cover an area of almost 85,000 square miles. Most of the rocks are related to the volcanic activity of the Aleutian Islands and to tectonic activity which formed the Aleutian Trench and the Islands. Most of the sedimentary rocks are of younger Tertiary age. No production of natural gas or oil has been established in the province and the potential for future natural gas production is very low.

P-991, P-992, P-993 AND P-994, NORTHERN GULF OF ALASKA AND SOUTHEASTERN ALASKA SHELF AND SLOPE

These provinces have a combined area of approximately 56,000 square miles. Sedimentary rocks are predominantly of Tertiary age and are generally detrital. No production of natural gas or oil has been established. Potential reservoir rocks include Tertiary formations. Both structural and stratigraphic traps occur and include truncations and onlap as well as anticlines and faulted anticlines. Potential source rocks may occur within the early Tertiary section.

P-995, COOK INLET BASIN-OFFSHORE

This province is the offshore portion of the Cook Inlet basin; the onshore portion is included in province P-707. It covers slightly more than 7,400 square miles. Sedimentary rocks in the province are predominantly detrital and range in age from Jurassic to Tertiary. This, and the adjoining onshore province, is the only area of current natural gas and oil production in Alaska outside of the North Slope. Two trends of natural gas production and two trends of oil production have been established.

Reservoir rocks. Sandstones and conglomerates of Tertiary age are the primary gas and oil reservoirs. The Tertiary Beluga and Sterling Sandstones are productive of gas only.

Traps. Sandstone pinchouts and antinclinal trapping are both common in the Tertiary section. Truncation by unconformities and faulted anticlines are common trapping mechanisms in Mesozoic reservoirs.

Potential source rocks. Thermally immature to mature Tertiary rocks are considered to be a fair source for oil. Late Jurassic, thermally moderately mature to very mature, rocks are considered to be good sources for oil and possibly for gas.

P-991, P-992, P-993, and P-994, NORTHERN GULF OF ALASKA AREA, SOUTHEASTERN ALASKA SHELF AND SLOPE
Generalized Stratigraphic Section

AGE	FORMATION	GENERAL LITHOLOGY
Cenozoic		
Tertiary	Tugidak Formation	sandstone, siltstone, mudstone
	#Yakataga Formation	mudstone and sandstone
	Sitkinak Formation #Katalla Formation-#Poul Creek Formation	mudstone, siltstone, sandstone
	#Tokun Formation	siltstone, sandstone, conglomerate
	Sitkalidak Formation-Orca Group-#Kulthieth Formation	sandstone and siltstone
	Ghost Rocks Formation	sandstone
Mesozoic	Kodiak Formation-Valdez Group-Yakutat Group	

Potentially productive

Table 17. Estimated resources of natural gas for provinces of the Alaska Area, December 1986 (billion cubic feet), page 1

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPECULATIVE		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-701, North Slope province	0-15,000'		12,000	5,920	2,000	43,000	15,000	4,000	72,000	23,000	6,000
	15-30,000'								NO RELIABLE DATA		
P-702, Brooks Range	0-15,000'								1,000	*	*
province	15-30,000'								NO DATA		
P-703, Yukon Flats-	0-15,000'								500	180	*
Kandik basins	15-30,000'								NO DATA		
P-704, Alaska Interior	0-15,000'								2,500	520	*
basins	15-30,000'								NO DATA		
P-705, Northern Gulf of	0-15,000'								3,550	710	120
Alaska, onshore	15-30,000'								NO RELIABLE DATA		
P-706, Southeastern Alaska	0-15,000'								*	*	*
	15-30,000'								*	*	*
P-707, Cook Inlet/Susitna	0-15,000'		1,600	670	400	2,800	1,400	700	4,800	2,400	*
province, onshore	15-30,000'								*	*	*
P-708, Alaska Peninsula/	0-15,000'								320	190	*
Shelikof province, onshore	15-30,000'								NO RELIABLE DATA		
P-709, Alaska Peninsula/Bristol	0-15,000'								1,400	690	380
Bay province, onshore	15-30,000'								NO RELIABLE DATA		
P-710, Aleutian Islands	0-15,000'								1,000	*	*
	15-30,000'								NO RELIABLE DATA		
P-971, Beaufort shelf		0-200 m	11,000	2,000	1,000	41,000	12,000	3,000	62,500	19,500	3,500
P-972, Beaufort slope		200-1,000m							NOT ESTIMATED		
P-973, Chukchi shelf		0-200 m							62,500	19,500	3,500
P-974, Norton basin		0-200 m							600	200	*
P-975, Hope basin		0-200 m							2,000	540	*
P-979, St. Matthew shelf		0-200 m							*	*	*

*Negligible quantity of natural gas estimated

Table 17. Estimated resources of natural gas for provinces of the Alaska Area, December 1986 (billion cubic feet), page 2

PROVINCE	ONSHORE	OFFSHORE	PROBABLE			POSSIBLE			SPECULATIVE		
	depth	water depth	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.
P-980, Southwestern Bering Sea		>1,000 m	NOT ESTIMATED--ALL WATER DEPTHS GREATER THAN 1,000 m								
P-981, Navarin basin shelf		0-200 m							4,000	1,000	*
P-982, Navarin basin slope		200-1,000m							500	*	*
P-983, St. George shelf		0-200 m							2,500	1,500	200
P-984, St. George slope		200-1,000m							500	*	*
P-985, Bristol Bay shelf		0-200 m							5,980	3,740	1,870
P-987, Shumagin shelf		0-200 m							5,200	1,720	220
P-988, Shumagin slope		200-1,000m							NOT ESTIMATED		
P-989, Aleutian shelf		0-200 m							1,000	*	*
P-990, Aleutian slope		200-1,000m							*	*	*
P-991, N. Gulf Alaska shelf		0-200 m							2,400	800	100
P-992, N. Gulf Alaska slope		200-1,000m							6,540	2,640	440
P-993, SE Alaska shelf		0-200 m							2,600	860	200
P-994, SE Alaska slope		200-1,000m							NO DATA		
P-995, Cook Inlet, offshore		0-200 m	800	400	200	1,400	700	350	2,400	1,000	*
TOTAL, onshore	0-15,000'			6,590			16,400			27,690	
TOTAL, onshore	15-30,000'			*			*			*	
TOTAL, onshore, all depths				6,590			16,400			27,690	
TOTAL, offshore		0-200 m		2,400			12,700			50,360	
TOTAL, offshore		200-1,000 m		*			*			2,640	
TOTAL, offshore, all depths				2,400			12,700			53,000	
GRAND TOTAL FOR AREA				8,990			29,100			80,690	

*Negligible quantity of natural gas estimated

NATURAL GAS RESOURCES FROM COAL SEAMS

INTRODUCTION

The resources of methane that may be recoverable from coal beds ("gaseous coal seams" were summarized in past reports of the Potential Gas Committee (1978, 1981). Since that time, considerable research by both government and industry, together with actual field testing and commercial production, have resulted in a degree of success now allowing coalbed methane to be a "conventional" resource.

Recognizing the growing importance of this resource, the Potential Gas Committee has approved the creation of a new work committee to evaluate the coalbed methane resource. The task of this new committee is to assess the size of the coalbed methane resource that is *recoverable* from the coal deposits of the United States. This committee is organized according to commodity, rather than by geography, as are the other PGC work committees. Although understanding of the coalbed methane resource has advanced rapidly, there are still many uncertainties regarding the magnitude of the recoverable resource. Therefore, coalbed methane is being treated in a separate chapter in this report. Estimates of *recoverable* coalbed methane resources will not be included in any of the geographic area estimates until such time as more quantitative data are available regarding the performance of coalbed methane wells, including reservoir behavior, drainage areas, rates of decline, and recovery efficiencies.

TECHNICAL BACKGROUND

Methane trapped, or occluded, in coal beds is a virtually untapped source of clean, sulfur-free, pipeline-quality energy that today constitutes an economically viable exploration and development objective. The production of gas from coal beds can be accomplished by drilling and completing vertical boreholes, utilizing essentially conventional technology, with some modifications, especially in the completion of such wells. In addition, many coalbed methane wells require dewatering of the coal, at least initially, by means of a variety of pumping arrangements. Most of the wells drilled for coal degasification require reservoir stimulation, usually through casing perforations, employing various combinations of hydraulic fracturing, such as sand-water, sand-foam, or sand-gel, in order to increase permeability to gas (figure 10).

The production of gas from coal beds, unlike in situ gasification techniques, is nondestructive to the coal, except possibly by the enlargement of already present cleats, or fractures, in the coal as a result of hydraulic fracturing. Furthermore, coalbed methane is high in heating value, generally between 900 and 1,050 Btu/Scf.

The coalification process, by which organic matter (e.g., wood, peat) is converted to coal, generates very large quantities of methane, both biogenic (i.e., formed by bacterial action in the early stages of diagenesis) and thermogenic (formed by thermal reactions during the phase of catagenesis). This gas is stored in high concentrations in both the coal and in the associated sediments after the gas-expulsion point in the coal has been attained. Volume-for-volume, high rank coals are capable of storing many times as much gas as are porous sandstone reservoirs under similar condtions of pressure, due to the extremely high internall surface areas of coals--as high as 1.5 million ft^2/lb, (or about

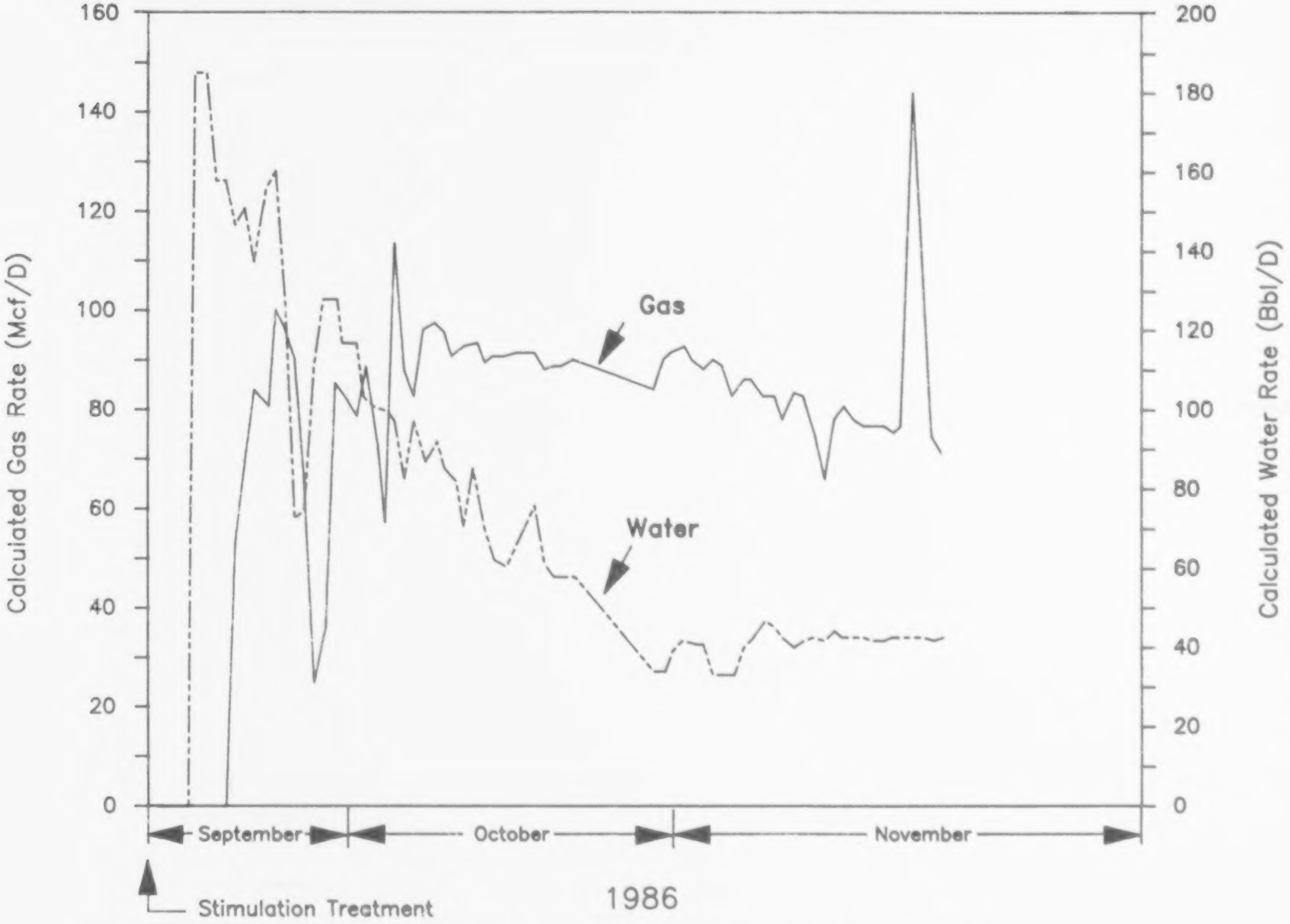


Figure 10. Typical response of gas and water production in a well in Black Warrior basin, Alabama to stimulation by hydaulic fracturing (courtesy of Lewin and Associates).

3,300 ft^2/g) (Cervik, 1969).

Until the last several years, methane from coal beds has been considered an "unconventional" resource because of the unique properties of coal, which constitutes both a source and a reservoir of natural gas. Coal is an extremely complex substance, one that still is incompletely understood. According to Van Krevelen (1961), coal has many attributes: it is a fuel, an organic sediment, a rock, a collection of plant debris, an organic chemical substance, a solid colloid, and a chemical reactant. It is not surprising, then, that such aspects as the reservoir behavior of coal are so difficult to predict and to model, unlike the more conventional sandstone or carbonate rock reservoirs.

In geologic basins such as the San Juan of Colorado and New Mexico and the Black Warrior of Alabama, the experience of certain petroleum industry operators has progressed to the point where coalbed methane now may be considered to be a conventional resource, albeit one possessing a number of unsolved technical problems, particularly in the area of production. In the San Juan basin it is estimated that between 125 and 150 wells currently are producing gas from coals in the Fruitland Formation (Upper Cretaceous). These wells produced a total of approximately 3 Bcf of gas during 1986 (Bruce Kelso, Colorado Geological Survey, private communication, 1987). There is undoubtedly considerable additional gas production from fruitland coals that is commingled with production from sandstones within the upper part of the Cretaceous sequence. In the Black Warrior basin, coalbed methane production in 1986 totalled more than 13 Bcf from wells located in seven gas fields (figure 11). Eighty percent of the total coalbed methane produced in the Black Warrior basin came from the 142 wells in the Brookwood field (Oil and Gas Journal, Sept. 8, 1986, p. 43).

An important characteristic of coalbed methane wells, in particular, those that initially produce water along with gas, is an *increase* in gas production with time and a corresponding *decrease* in water production (figure 12). This gas production *incline* may persist for a number of years before the inevitable decline occurs. Based on limited, but well-documented, production histories, it appears that typical coalbed methane wells will be long-lived.

When optimum conditions of rank, gas saturation, reservoir temperature, coal permeability, and other critical factors are present, a high rate of success should be experienced in the development of a coalbed methane field or pool. The ubiquitous nature of methane in coal beds generally is independent of structural position in a basin—i.e., whether anticlinal or synclinal—except where structural deformation may affect the permeability of a coalbed reservoir.

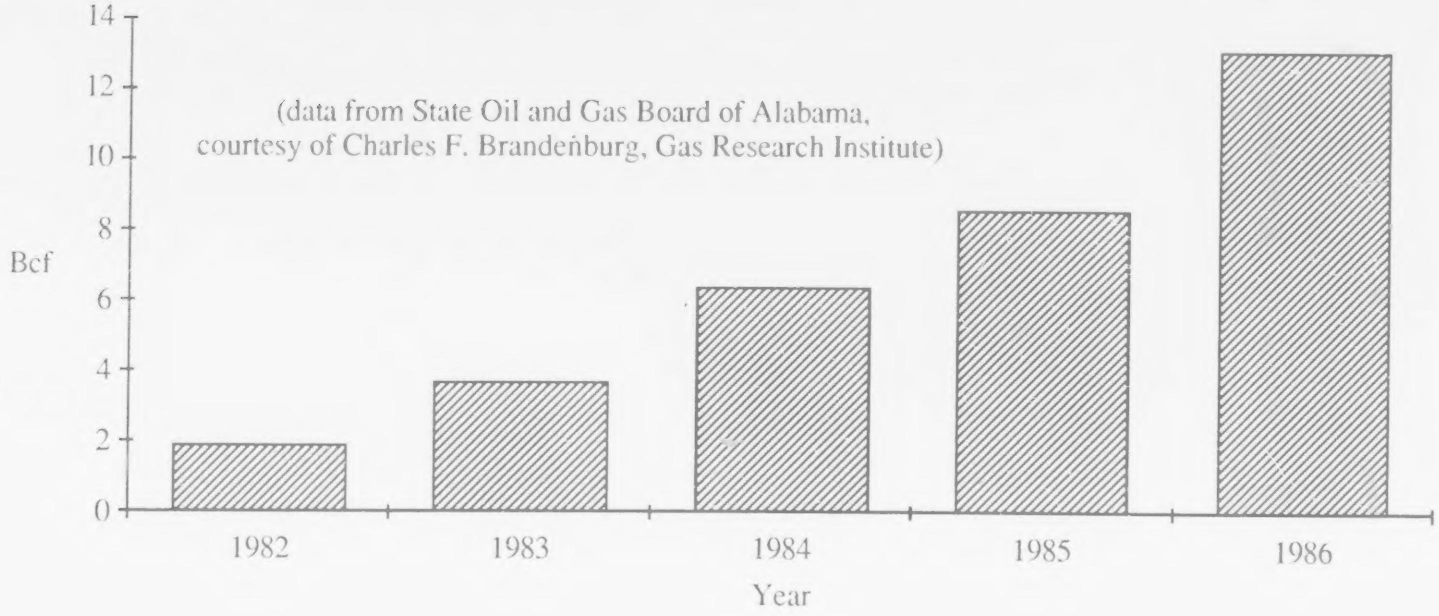
The resource base of coalbed methane in the United States alone is indeed immense. Preliminary estimates, based on very incomplete data, place this resource in the range of 400 to 800 or more trillion cubic feet (Tcf) *in-place*. Estimates for individual basins vary from a few Tcf to more than 80 Tcf (Rightmire, Eddy and Kirr, 1984; Lewin and Associates, Inc., 1987 [a,b]).

PRODUCTION OF COALBED METHANE

Methane has been produced from coal beds through boreholes since the turn of the century. These holes include water wells and degasification holes (ranging from vertical to horizontal) designed to drain as much methane as possible for safety reasons from virgin coal seams prior to mining (Skow, Kim, and Deul, 1980). A number of production case histories are described in Tilton (1976), TRW Energy Engineering Division (1981), Murray (1981), Rightmire, Eddy, and Kirr (1984), Choate, McCord, and Rightmire (1986), Trevits and Finfinger (1986), Tew and Mancini (1986), and Shirley (1986).

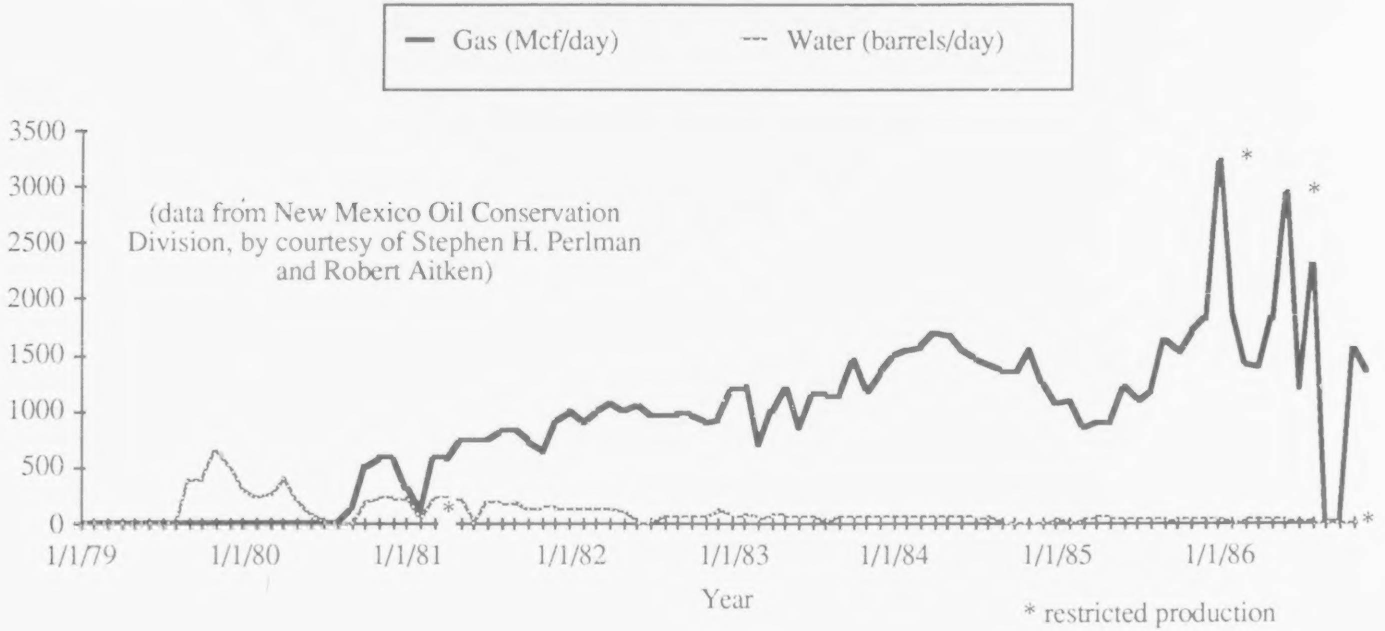
A paper essential to the understanding of the behavior of coal-gas reservoirs was prepared by Cervik (1969), who observed that gas occurs in coal beds in both an adsorbed and a free state. Adsorbed gas is stored in the matrix, or micropores, of the coal and desorbs and diffuses through the coal at a rate governed by the diffusion process described by Fick's law or by other diffusion models, the driving force being a concentration gradient. Once the gas has migrated into the larger pores and into the cleat and fracture system, it then will flow into the well bore (or mine) according to Darcy's law, being driven by pressure gradient. These two types of mass transport are interdependent. The majority of coalbed reservoirs are at essentially hydrostatic pressure; and they depend on a system of fractures and cleats for most of their

Figure 11. Coalbed methane production in the Black Warrior basin, Alabama



(data from State Oil and Gas Board of Alabama, courtesy of Charles F. Brandenburg, Gas Research Institute)

Figure 12. Production history of Amoco Cahn #1 well, Cedar Hills Field, San Juan basin, New Mexico.



(data from New Mexico Oil Conservation Division, by courtesy of Stephen H. Perlman and Robert Aitken)

* restricted production

permeability. The relative permeabilities to both gas and water are critical to the initial production of methane from coalbed reservoirs. In water-saturated coals, water must be removed (usually by pumping) in order to upset the equilibrium that exists between the methane absorbed within the micropores and that existing in the fracture system. Once a pressure gradient has been established, methane will first diffuse into the fracture system and then flow from the fractures into the wellbore, where the pressure has been lowered to less than hydrostatic.

Ultimately, the productivity of a coalbed gas well will be largely dependent upon the ability to lower reservoir pressure and water saturation (if present) in the coalbed reservoir. A multiwell pattern is necessary in order to create drainage boundaries or areas of interference. Kissell and Edwards (1975) have demonstrated that by lowering the water saturation in the fractures and cleats in the coal, the effective permeability to gas is increased (i.e., more space is made available to the gas phase), resulting in an *increasing* rate of gas production and a corresponding *decrease* in rate of water production. Such "negative declines" have been observed in a number of coalbed methane wells in productive areas such as the San Juan and Black Warrior basins (Rightmire, Eddy, and Kirr, 1984; and Choate, McCord, and Rightmire, 1986).

Drilling and production activities involving coalbed methane wells in the most active areas in the United States--the San Juan, Black Warrior, Piceance, and Raton basins, and western Washington State--are summarized in the issues of the *Quarterly Review of Methane from Coal Seams Technology,* published by Gas Research Institute.

The following is a brief summary of recent coalbed methane activity, derived largely from the *Quarterly Review:*

1. Black Warrior Basin, Alabama: From 1980 through mid-1986, 354 coalbed methane wells were drilled in the basin, of which 275 were producing during June 1986. Cumulative production as of July 1, 1986, was 26.013 Bcf gas. Total production in 1986 from coalbed methane wells in the Black Warrior basin was 13 Bcf.Production in May 1986 from coal beds in the Pottsville Formation (Lower Pennsylvanian) was 1.035 Bcf, 14 percent of Alabama's total gas production, from seven coalbed methane fields. Of this amount, 80 percent came from Brookwood field (Oil and Gas Journal, September 8, 1986, p. 43). Most of the coal gas wells in the basin produce from depths varying from approximately 1,000 to 1,300 ft. Initial production rates range from less than 50 to more than 2 MMcfd, often with associated water.

2. San Juan Basin, Colorado and New Mexico: This basin constitutes the most active area of coalbed methane exploration and production in the western U.S., with several dozen wells being reported in various stages of updating, drilling, or completion in recent issues of the *Quarterly Review.* It is estimated that between 125 and 150 wells currently are producing, or are capable of producing, gas from coals in the Fruitland Formation (Upper Cretaceous) and that these wells produced a total of about 3 Bcfg during 1986 (Bruce Kelso, Colorado Geological Survey, private communication, 1987). In the Rocky Mountain region, data concerning coalbed methane wells are not readily available from State agencies, inasmuch as coalbed methane wells and production in these areas are not permitted and reported separately from "conventional" oil and gas wells, as they are in Alabama. Most coal degasification wells in the San Juan basin produce from depths in the range of ±1,200 to 4,100 ft. Initial production rates vary from less than 50 to more than 3 MMcfd, usually with some associated water.

3. Piceance Basin, Colorado: Considerable exploratory effort is being expended in this large, deep basin in western Colorado, in which sizeable Federal oil and gas units (up to 150,000 acres in size) have been assembled in order to expedite coalbed methane exploration. To date, only a few wells have been successfully completed in the basin in coals in the Mesaverde Group (Upper Cretaceous), with initial production rates as high as ±500 Mcfd from depths ranging from 3,750 to 8,800 ft.

4. Raton Basin, Colorado-New Mexico: Probably less than two dozen wells have been drilled during the past eight years in this basin that were specifically designed to test the coalbed methane potential of the Raton (Paleocene) and Vermejo Formations (Upper Cretaceous). Most of these are less than 3,000 ft in depth. Reported initial production rates have been 30 Mcfd or less, with water rates as high as 135 BPD. Industry activity in this basin currently is at a relatively low level.

5. Western Washington State: To date, none of the dozen or so wells drilled to explore for coalbed methane on the western edge of the Cascade Range has met with success. These holes, most of which are less than 2,500 ft in depth, were designed to test coalbeds found chiefly in the Puget Group (Eocene) or its equivalents.

RESOURCES OF COALBED METHANE

As shown in Choate, McCord, and Rightmire (1986, Table 1), a wide range of estimates pertaining to total in-place coalbed methane resources in the conterminous United States have been published since 1978. These estimates vary from a minimum of 72 Tcf to a maximum of 860 Tcf, with estimates of *recoverable* resources ranging from 10 to 487 Tcf. All of these estimates must be considered as very preliminary because they are based on incomplete data regarding both the magnitude and character of US coal resources below 3,000 ft in depth and on the in situ gas content of most of the coal beds involved. If one uses the data presented in Averitt (1975), the following estimate could be made: Estimated remaining coal resources in the United States, as of January 1, 1974, including total identified and hypothetical resources remaining in the ground beneath 0 to 6,000 ft of overburden are 3,968 billion short tons (or approximately 4 trillion ST). If only 50 percent of this resource has an in situ methane content of 200 ft^3/ton (6.25 cc/g), then the total in situ coalbed methane resource of the United States, *including Alaska*, could be on the order of *400 Tcf*. This probably is a conservative figure for several reasons: (1) The total remaining US coal resource in the ground is believed to be considerably more than 4 trillion tons, based on more recent resource studies and on the fact that thick coal beds are known to exist below the 6,000 ft depth cutoff used by Averitt (1975) (in fact, coals occur at depths greater than 10,000 to 15,000 ft in some basins in the Rocky Mountain region); and (2) the gas content of many deposits of coal in the subsurface (principally, below 500 to 1,000 ft) exceeds 200 ft^3/ton (6.25 cc/g), as shown by Rightmire, Eddy, and Kirr (1984) and Diamond, La Scala and Hyman (1986). Published maps (as in Averitt, 1975; and Rightmire, Eddy, and Kirr, 1984) also do not accurately represent the rank of all the coal deposits known to exist in many of the western US basins, especially of those coals occurring below minable depths.

The following table (table 18) summarizes the coalbed methane resource of thirteen major coal-bearing basins in the conterminous United States as determined by studies sponsored by the US Department of Energy Methane Recovery from Coalbeds Project (MRCP) conducted by TRW geologists (Rightmire, Eddy, and Kirr, 1984), the University of Alabama (Tew and Mancini, 1986), and the Gas Research Institute (Lewin and Associates, Inc., 1987[a,b]) (figure 13).

If 50 percent of the 400+ Tcf of coalbed methane estimated to be in-place in the thirteen basins evaluated above eventually could be recovered by future drilling, the contribution to the future gas supply of the United States indeed would be significant.

A program is currently underway, sponsored by the Gas Research Institute's Natural Gas Supply Program, to determine the coalbed methane that is economically recoverable from the more important coal-bearing basins in the United States, utilizing advanced production technologies. This program will aid greatly in refining the resource figures listed in Table 18. Assessments of coalbed methane for the Black Warrior and Piceance basins have been completed, and studies have been started in the Appalachian and San Juan basins.

CONCLUSIONS

Coal constitutes one of the richest sources of hydrocarbons known. The coalification process generates very large volumes of methane--more than 8,000 cubic feet per ton of high-rank coal--that is both biogenic and thermogenic in origin. Coal is an extremely complex organic substance and possesses the unique capability of being both a source and a reservoir of natural gas. Consequently, the reservoir behavior of coal, its production characteristics, and other aspects so important to the natural gas industry are difficult to predict and to model. In this sense, coalbed reservoirs can be considered "unconventional."

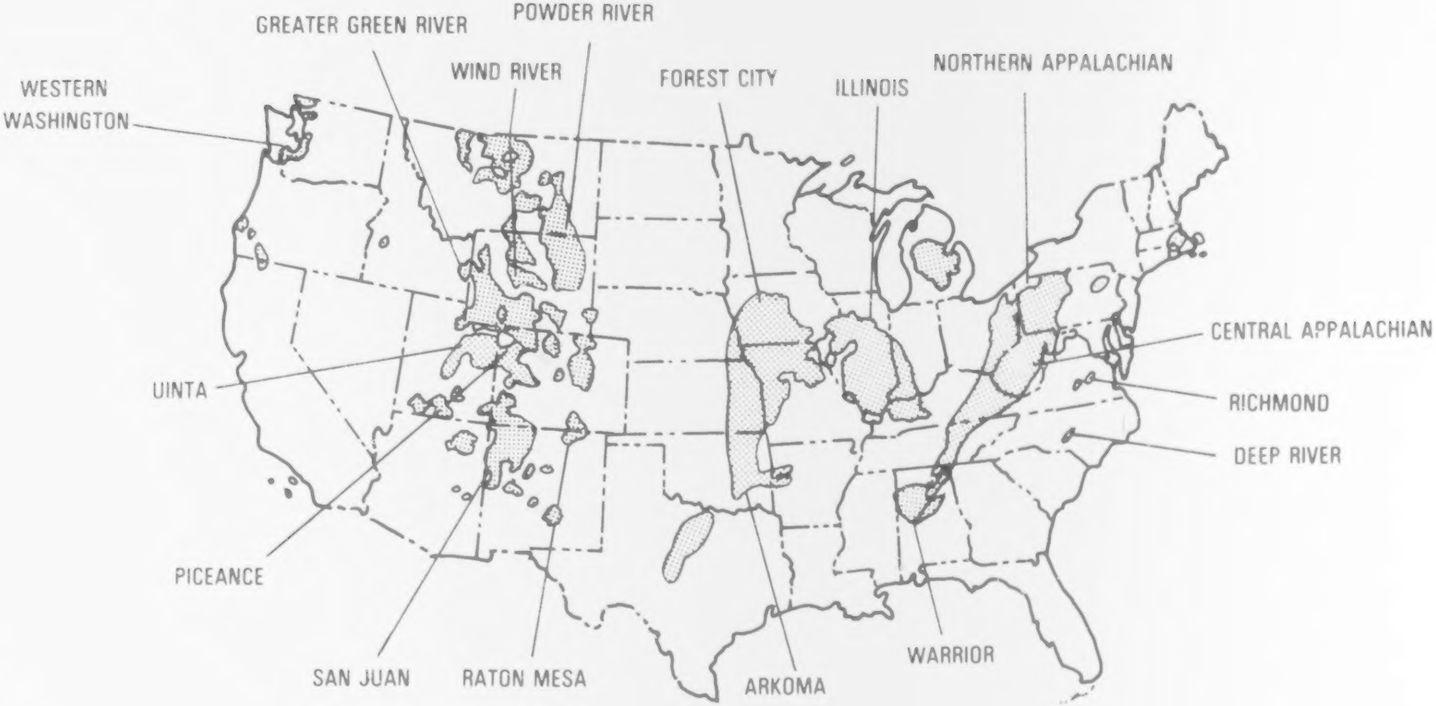

GREATER GREEN RIVER
POWDER RIVER
WIND RIVER
FOREST CITY
ILLINOIS
NORTHERN APPALACHIAN
WESTERN WASHINGTON
CENTRAL APPALACHIAN
RICHMOND
DEEP RIVER
UINTA
PICEANCE
SAN JUAN
RATON MESA
ARKOMA
WARRIOR

Figure 13. Map of major coal regions in the conterminous United States (from Mroz, Ryan and Byrer, 1983)

Table 18. Estimated in-place coalbed methane resource, selected basins in conterminous United States

PGC Region	Basin	PGC Province No.	State(s) included in evaluation	Estimated total methane in place (Tcf)	Estimated total most likely recoverable resource all resource categories (Tcf)
Eastern	Appalachian central*	P-120	KY, MD, TN, WV, VA	10.0 to 48.0 (1)	(not estimated)
	Appalachian northern*	P-120	KY, MD, OH, PA, WV	61.0 (1)	(not estimated)
	Warrior (Black Warrior)*	P-150	AL, MS	5.0 to 10.0 (1) 19.8 (2) 39.0 (3)	(not estimated) 7.7 (2) 15.0 (3)
	Illinois	P-220	IL, IN, KY	5.2 to 21.1 (1)	(not estimated)
	Arkoma	P-410	AR, OK	1.6 to 3.6 (1)	(not estimated)
Western	Powder River	P-510	MT, WY	5.9 to 39.4 (1)	(not estimated)
	Wind River	P-520	WY	0.5 to 2.2 (1)	(not estimated)
	Greater Green River	P-530	CO, WY	0.2 to 30.9 (1)	(not estimated)
	Piceance*	P-540	CO	30.0 to 110.0 (1) 83.9 (2)	(not estimated) 29.7 (2)
	Uinta/Wasatch Plateau	P-540	CO, UT	0.2 to 0.8 (1)	(not estimated)
	Raton Mesa (Raton)	P-545	CO, NM	8.0 to 18.4 (1)	(not estimated)
	San Juan*	P-555	CO, NM	1.8 to 31.0 (1)	(not estimated)
	Western Washington	P-600	WA	3.6 to 24.0 (1)	(not estimated)
TOTAL				72.0 to 429.4	44.7

*Commercial coalbed methane production known to be established

(1) DOE MRCP (TRW)
(2) GRI (Lewin)
(3) University of Alabama

However, the growing successful experience of operators in such basins as the San Juan of Colorado and New Mexico and the Black Warrior in Alabama has advanced to the place where coalbed methane now may be treated as a conventional resource. Coalbed methane is an attractive exploratory objective for reasons that include the relatively shallow depths of most coal deposits, the ubiquitous occurrence of gas in coal, and the very large gas generation and storage capacities of higher rank coals. Furthermore, coal gas wells typically experience an *increase* in gas production with time, and a corresponding *decrease* in water production, if any. The production *incline* of coalbed methane wells is expected to persist for a number of years, based on the few well-documented production histories that are available.

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POLICY GUIDELINES

General Policy Statement

An appraisal of the long-range prospects of the natural gas industry in the United States--an appraisal that is useful for financial, managerial and government purposes--requires, as an essential element, scientific, authoritative, and objective estimation of the potential supply of natural gas which may become available to the nation in addition to currently available proved recoverable reserves of natural gas.

The Potential Gas Committee fulfills this requirement by providing periodic estimates of the potential supply of natural gas which may become available. The PGC, together with its several Area Work Committees, is composed of about one hundred fifty individuals from the production, transmission and distribution segments of the natural gas industry who are knowledgeable with respect to the potential supply of natural gas.

The Committee functions independently but with the guidance and assistance of the Potential Gas Agency of the Colorado School of Mines. The Potential Gas Agency is supported by the American Gas Association.

The PGC and its Area Work Committees discuss matters and data that are confidential. Fulfillment of the objectives of the PGC cannot be realized without the availability and utilization of information of a highly confidential nature. It is, therefore, the policy of the PGC and its Work Committees that every member, observer and representative will respect such information and that there will be no disclosure of information or estimates, discussions, or other data, except as approved for release by the PGC.

A diagram of the organizational structure for the estimation of the potential supply of natural gas is shown in figures 14 and 15. A detailed description of the membership and duties of the several committees and of the PGC is presented in the sections which follow.

Gas Supply Committee of the American Gas Association

The membership of the Gas Supply Committee consists of representatives of member companies of the American Gas Association selected by the Chairman of the Board and approved by the Board of Directors of the American Gas Association.

The scope of the Committee is to coordinate, motivate and make recommendations to the Board of American Gas Association as to the areas in which A.G.A. should become more active in the development of adequate gas supply for both short-term and long-term. In addition, the Committee undertakes special projects, where necessary, to evaluate industry gas supply programs. The Gas Supply Committee oversees the work of the Potential Gas Agency.

The primary duties and responsibilities of the Gas Supply Committee with relation to potential gas studies include the following:

a. Establishing policy and objectives.

b. Providing required financial support.

c. Maintaining liaison with industry and industry organizations.

d. Selecting the Potential Gas Agency.

e. Approving the appointment of the President/General Chairman and Regional Vice Presidents of the Potential Gas Committee by the Potential Gas Agency.

f. Appointing pipeline and distributor representatives to the Potential Gas Committee as may be necessary or advisable.

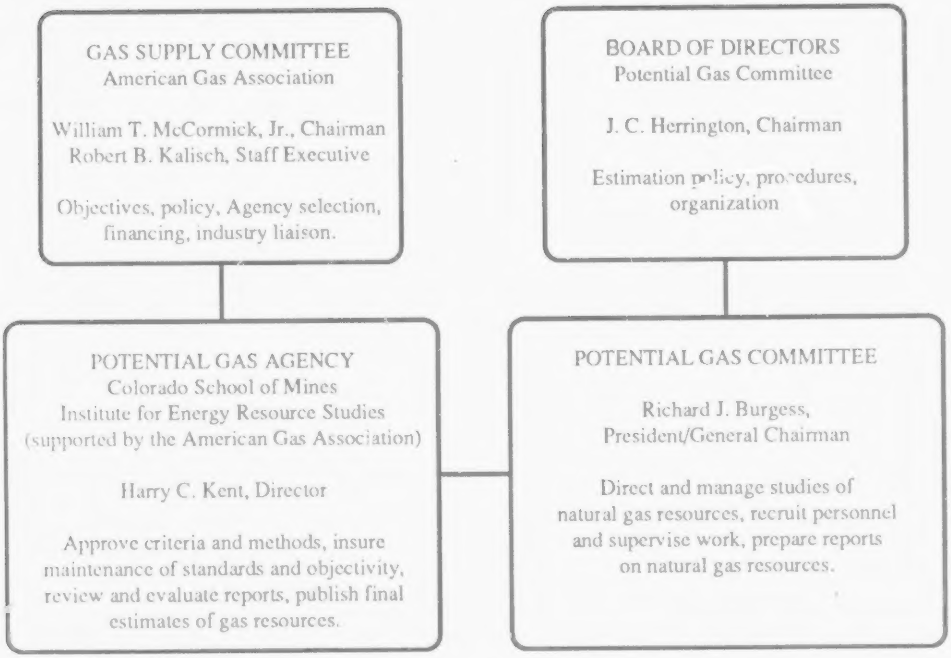
GAS SUPPLY COMMITTEE
American Gas Association
William T. McCormick, Jr., Chairman
Robert B. Kalisch, Staff Executive
Objectives, policy, Agency selection, financing, industry liaison.
BOARD OF DIRECTORS
Potential Gas Committee
J. C. Herrington, Chairman
Estimation policy, procedures, organization
POTENTIAL GAS AGENCY
Colorado School of Mines
Institute for Energy Resource Studies
(supported by the American Gas Association)
Harry C. Kent, Director
Approve criteria and methods, insure maintenance of standards and objectivity, review and evaluate reports, publish final estimates of gas resources.
POTENTIAL GAS COMMITTEE
Richard J. Burgess,
President/General Chairman
Direct and manage studies of natural gas resources, recruit personnel and supervise work, prepare reports on natural gas resources.

Figure 14. Organization of potential gas resource studies.

g. Appointing such other members and observers to the Potential Gas Committee as may be necessary or advisable.

h. Assisting in procurement of qualified manpower to staff properly the Potential Gas Committee and the Area Work Committees.

The Gas Supply Committee of the American Gas Association takes no part in the work or the deliberations of the Potential Gas Committee or its sub-committees. The Gas Supply Committee does not participate in the studies leading to the estimates of potential supply of natural gas, and it neither approves nor disapproves the definitions and procedures, the estimates, or the report.

Potential Gas Agency of the Colorado School of Mines

The Potential Gas Agency functions under the direction of the Vice President for Academic Affairs of the Colorado School of Mines. The School, with the approval of the Gas Supply Committee, appoints staff personnel to the Potential Gas Agency.

The Potential Gas Agency is supported by the American Gas Association. The American Gas Association is free, however, to take independent views of the operations and the studies produced by the Agency and its committees. The Agency is charged with the maintenance of scientific standards and objectivity of studies and publishes the reports of

POTENTIAL GAS COMMITTEE

Richard J. Burgess, President/General Chairman

J. C. Herrington, Chairman, Board of Directors
and Chairman, Time and Site Committee

David A. Rochester, Secretary

William E. Mantek, Chairman, Editorial Committee

Under direction of Potential Gas Agency, outline study; establish criteria and methods; designate and instruct Area Work Committees; supervise, coordinate and compile estimates made by Work Committees.

Membership:

(a) President/General Chairman and Regional Vice Presidents--
appointed by Potential Gas Agency and approved by A.G.A. Gas Supply Committee.
(b) Area Work Committee Members.
(c) Potential Gas Agency Director, Ex officio.
(d) Technical Advisors and Honorary Technical Advisors
(e) A.G.A. staff--one voting representative.
(f) One Pipeline and one Distributor representative, designated by the Gas Supply Committee--voting representatives.
(g) Observers from the federal government: Department of Energy, Energy Information Administration; Federal Energy Regulatory Commission; Department of Interior, Geological Survey, Bureau of Land Management, Minerals Management Service, Bureau of MInes; and such other governmental agencies as the Gas Supply Committee and the Potential Gas Agency shall approve--one nonvoting observer each, and alternates, if desired.
(h) Gas Research Institute, Institute of Gas Technology, Natural Gas Supply Association,Electric Power Research Institute, Association of American State Geologists, Interstate Natural Gas Assocation of America, National Assocation of Regulatory Utilities Commissioners and Interstate Oil Compace Commission --one nonvoting observer each, and alternates, if desired.
(i) Canadian and Mexican natural gas industry--one nonvoting observer each, and alternates, if desired.
(j) Others appointed by the Gas Supply Committee and approved by the Potential Gas Agency.

AREA WORK COMMITTEES

EASTERN REGION

Jeffery V. Morris, Regional Vice President
Porter J. Brown, Assistant Vice President

Area	Chairman
Atlantic	George C. Grow, Jr.
North Central	Michael W. Barratt
Gulf Coast	J. Scott Jenkins
Mid-Continent	Mike H. Knobloch

WESTERN REGION

Robert D. Habbit, Regional Vice President
D. Keith Murray, Assistant Vice President

Area	Chairman
Rocky Mountain	H. O. Woodbury
Pacific	K. E. Wainwright
Alaska	Donald C. Hartman
Coalbed Methane	D. Keith Murray

Figure 15. Organization of Potential Gas Committee.

the Potential Gas Committee. The Agency appoints the President/General Chairman and Regional Vice Presidents of the Potential Gas Committee, approves the appointment of members, representatives and observers to the Potential Gas Committee and the chairmen of all sub-committees.

The Potential Gas Agency includes the following:

a. A Director, appointed by and responsible to the Colorado School of Mines.

b. Such additional staff personnel as may be required.

c. Members of the faculty of the Colorado School of Mines or other qualified individuals who may, from time to time, provide such professional services as the Director of the Potential Gas Agency and the President/General Chairman of the Potential Gas Committee may determine necessary or desirable for discharging the duties of the Potential Gas Agency and the Potential Gas Committee.

The primary duties and responsibilities of the Potential Gas Agency include the following:

a. Approving criteria and methods established by Potential Gas Committee, including protecting the confidentiality of Potential Gas Committee data.

b. Insuring maintenance of the highest scientific standards and objectivity in Potential Gas Committee studies and reports.

c. Reviewing and evaluating reports prepared by the Potential Gas Committee.

d. Publishing, distributing and publicizing reports of final estimates and other pertinent reports prepared by the Potential Gas Committee so as to assure the widest possible distribution and to promote understanding of them.

e. Further develop mutual understanding among the segments of the gas industry by helping the Gas Supply Committee unite the industry behind the potential gas studies.

f. Help improve industry-government relations in the public interest looking toward maximum acceptance and usefulness of potential gas studies.

g. Fulfill the professional obligation to publish technical papers concerning new techniques and knowledge gained.

h. Appointing President/General Chairman and Vice Presidents of Potential Gas Committee, with approval of Gas Supply Committee.

i. Approving appointment by Gas Supply Committee of other members, representatives and observers to the Potential Gas Committee.

j. Approving appointment of President/General Chairman of Potential Gas Committee, of Chairman of each Work Committee and chairmen of other committees.

k. Conduct the work of the Potential Gas Agency, in the public interest, in a manner which will enhance the stature of the Colorado School of Mines.

l. Adhere to the highest standards of objectivity.

The Colorado School of Mines may pursue other research, and individuals from the Agency may be involved in other research, consulting and preparation and publication of papers in their professional fields, so long as these activities do not involve a conflict of interest nor invalidate the objectivity of the Agency.

Potential Gas Committee

The Potential Gas Committee comprises members, representatives and observers from the producing, pipeline and distribution branches of the gas industry, together with observers from the American Gas Association, the Department of Energy, the Federal Energy Regulatory Commission, the US Geological Survey, the National Association of Regulatory Utility Commissioners, the Interstate Oil Compact Commission, the Bureau of Mines, the Gas Research Institute, Institute of Gas Technology, Association of American State Geologists, Electric Power Research Institute, Natural Gas Supply Association, Energy Information Administration, Interstate Natural Gas Association of America, Bureau of Land Management, Minerals Management Service and representatives from Canada.

The President/General Chairman of the Potential Gas Committee is assisted by the two Regional Vice Presidents and by a Board of Directors, composed of senior members of the Potential Gas Committee, including past chairmen. It is the function of the Board of Directors to advise the President/General Chairman on policy matters.

An Editorial Committee is charged with approving the content of the report of the Potential Gas Committee.

The Definitions and Procedures Committee has the responsibility of reviewing and recommending to the membership of the Potential Gas Committee any proposed changes in the definitions and procedures used in the estimation of potential gas resources.

Membership of the Potential Gas Committee specifically includes the following:

a. President/General Chairman of Potential Gas Commitee.
b. Secretary of Potential Gas Committee.
c. Regional Vice Presidents and Assistant Vice Presidents.
d. Chairman of each Area Work Committee.
e. Chairman of Board of Directors.
f. Chairman of Editorial Committee.
g. Chairman of Committee on Definitions and Procedures.
h. Chairman of Time and Site Committee.
i. Director of the Potential Gas Agency, ex officio.
j. Observers from:
    Association of American State Geologists
    Bureau of Land Management
    Bureau of Mines
    Department of Energy
        Energy Information Administration
    Electric Power Research Institute
    Federal Energy Regulatory Commission
    Gas Research Institute
    Institute of Gas Technology
    Interstate Natural Gas Association of America
    Interstate Oil Compact Commission
    Minerals Management Service
    National Association of Regulatory Utility Commissioners.
k. Representative from the natural gas pipeline industry.
l. Representative from the natural gas distribution industry.
m. Representative from the American Gas Association
n. Observer from the Canadian natural gas industry and observer from the Mexican natural gas industry.
o. Technical Advisors and Honorary Technical Advisors.
p. Representatives and observers from other organizations may be recommended for appointment by the Potential Gas Agency Director and approved by the Gas Supply Committee.

All members of the Potential Gas Committee, except those specifically designated as observers, are considered as voting members of the Potential Gas Committee. Observers are invited and encouraged to participate in discussion of items brought before the Potential Gas Committee but do not have a vote in the determination of policy and procedure. Alternates to representatives and observers may be appointed.

Candidates for Committee President/General Chairman and Vice Presidents normally will be geologists or persons with geology background from the academic community, pipelines, independent firms, gas utilities or producing companies. Retired or semi-retired gas industry people are not excluded from consideration.

Officers of the Potential Gas Committee and Area Work Committees are appointed as outlined in the Organizational Chart (fig. 9). Normally they serve for a period of one report. They are eligible for reappointment, however, for one additional report period. In calculating eligibility for reappointment, a partial term of office shall not be counted. This policy shall not operate to disqualify a member from longer service by reason of elevation in the organization. In other words, the two-term limitation shall apply to each position held, considering each membership or officership on a work committee or top committee as a separate position.

All officers, regional vice presidents and the pipeline and distributor representatives appointed by the American Gas Association Gas Supply Committee shall be subject to the two-report limit. Exceptions must be recommended by the appropriate Committee Chairman and the Potential Gas Agency Director and approved by the American Gas Association Gas Supply Committee.

Technical Advisors include persons who have special knowledge of the occurrence of natural gas or the natural gas industry and whose expert advice will contribute to the successful performance of the Committee's assignments. Past Chairmen of Work Areas and Past Regional Vice Presidents of the Potential Gas Committee will be appointed as Technical Advisors if they are willing to continue to participate in the work of the Committee. The appointment of Technical Advisors is approved by the Gas Supply Committee upon recommendation by the Potential Gas Agency Director. Technical Advisors are appointed for the preparation of a specific PGC report. Their appointment may be continued indefinitely but is subject to review and approval at the time of organization of the Potential Gas Committee for each succeeding report.

The designation of Honorary Technical Advisor may be given to such persons as have performed exceptional service to the Potential Gas Committee and whose continued participation and advice are desirable for the continued successful operation of the Committee. Honorary Technical Advisors are permanent voting members; their appointment is recommended by the Board of Directors and approved by the Potential Gas Agency Director and the Gas Supply Committee.

Observers from sponsoring associations, governmental agencies and other cooperating groups serve at the discretion of these organizations and are not subject to the two-report policy.

The primary duties and responsibilities of the Potential Gas Committee include the following:

a. Outlining the scope and coverage of the estimates of potential natural gas supply.
b. Establishing criteria and methods for estimation of potential natural gas supply and other pertinent studies.
c. Designating Work Areas and Special Projects.
d. Appointing the Chairman of each Area Work Committee (by action of President/General Chairman of Potential Gas Committee).
e. Approving appointment of other members of each Area Work Committee who are appointed by the Chairman of each Area Work Committee (by action of President/General Chairman of Potential Gas Committee).
f. Instructing Area Work Committees.
g. Supervising, coordinating, advising, reviewing, evaluating, approving and compiling estimates and such other assignments as may be given to committees.
h. Preparing reports of final estimates and such other reports as may be pertinent.
i. Submitting reports of final estimates and other pertinent reports to the Potential Gas Agency and counseling with Director regarding publication and distribution of such report.

Area Work Committees

Seven Area Work Committees are the backbone of the Potential Gas Committee. Each of the Work Committees has the responsibility of developing an estimate of the potential supply of natural gas in a particular part of the United States. Following the system long used by the petroleum industry, each Area Work Committee is assigned geologically significant areas (without specific regard to state lines) in which the Committee members have expert working knowledge. These Committee members with their fund of information (often confidential), are the source of knowledge and judgment for estimating the undiscovered gas supply in each area. Because geologic rather than geographic divisions are used, publication of estimates by individual states is not feasible.

The membership of Area Work Committees consists of employees and consultants associated with the producing, pipeline and distribution segments of the gas industry--as well as qualified personnel from State and Federal Agencies and educational institutions.

For administrative purposes, the Area Work Committees are grouped together in two regions: Eastern and Western. Each of these regions is supervised by a Regional Vice President who coordinates activities of the Area Work Committees within his jurisdiction and works with the Potential Gas Committee President/General Chairman in order to assure that there is an open flow of communication in both directions, and that the established techniques for resource estimation are being followed by the Area Work Committees.

Membership of Area Work Committees includes the following:

a. Chairman of each Area Work Committee.
b. An appropriate number of qualified working members deemed necessary by the Chairman of each Work Committee to insure the most objective estimates of potential supply of natural gas in the respective area assigned. Work Committee members are individuals from the natural gas and oil industries and other individuals who are qualified by their knowledge and experience to make estimates of potential supply of natural gas. The individuals are selected for each area because they have a close, working knowledge in all aspects of natural gas exploration and production.
c. At least one qualified representative on each Area Work Committee from the natural gas pipeline industry, appointed by the Gas Supply Committee. (This requirement is currently waived for the Alaska Committee.)
d. At least one qualified representative on each Area Work Committee from the natural gas distribution industry, appointed by the Gas Supply Committee. (This requirement is waived for the Alaska Committee.)

The Chairman and Vice Chairman of each Area Work Committee are subject to the two-report limit. Exceptions must be recommended by the Regional Vice President, approved by the Potential Gas Committee President/General Chairman and the Potential Gas Agency Director, and reported to the Gas Supply Committee, and only after receiving a clearance letter from the member's employer.

Other members of the Area Work Committees, appointed by the Area Chairman, will normally participate in the preparation of two successive reports. Service beyond the preparation of two reports may be continued if necessary to maintain adequate expertise and continuity on the Area Work Committee. Continuation of service beyond two reports must be recommended by the Area Chairman and approved by the Regional Vice President, the Potential Gas Committee President/General Chairman, and the Potential Gas Agency Director.

The primary duties and responsibilities of Area Work Committees include the following:

a. Appointing appropriate number of qualified working members to insure proper representation of various sectors of the industry and objectivity for the best estimates of potential supply of natural gas for assigned areas (by action of Chairman of each Area Work Committee).
b. Estimating quantity of potential supply of natural gas in working areas designated by the Potential Gas Committee pursuant to the guidelines and parameters established by the Potential Gas Committee, and approved by the Potential Gas Agency, and such other studies as may be assigned by the Potential Gas Committee.
c. Peforming such other assignments as may be made in the respective area assigned by the Potential Gas Committee regarding such estimate.

Each member of each Area Work Committee will submit his estimates of potential supply of natural gas and such other assignments as may be given to him in his assigned sub-area to the Chairman and other members of his committee for review, evaluation and approval.

Since the type and quantity of available information upon which to base estimates of potential natural gas supply vary widely from area to area, the Area Work Committee members use varied approaches in making their estimates. Inasmuch as the individual members work with private information obtained on a confidential basis from many sources, their working papers are not revealed in detail to anyone, including other members of the same Area Work Committee or others in the Potential Gas Committee. Without such confidential information, the Potential Gas Committee could not perform its task; therefore, each member, observer or representative of the Work Committees is aware of and must respect the confidential nature of the data made available to him and of the estimates and other assignments prepared or reviewed by the Area Work Committees and the Potential Gas Committee.

Standing Committees of the Potential Gas Committee

Board of Directors

The Board of Directors shall serve as the administrative coordinating committee for the Potential Gas Committee. It shall consider and discuss any matters of policy which are brought to its attention and shall make recommendations to the Potential Gas Committee regarding changes in policy. It shall act on behalf of the Potential Gas Committee on matters of urgency which arise between regularly scheduled meetings of the Potential Gas Committee. It may also be empowered to act on behalf of the Potential Gas Committee on matters designated by the Potential Gas Committee. At such times as vacancies occur in the following offices, the Board of Directors shall either act as a nominating committee to recommend suitable candidates or appoint a nominating committee from among its membership: PGC President/General Chairman, Regional Vice Presidents, Secretary of the PGC and Chairman of the Board of Directors.

Chairmen of PGC standing committees, with the exception of the Board of Directors, will be appointed by the PGC President/General Chairman, subject to approval by the Board of Directors. All actions of the Board of Directors will be reported to the membership of the Potential Gas Committee at their next regularly scheduled meeting and shall be subject to review and approval by the Potential Gas Committee.

Membership

Chairman, elected from the membership of the Potential Gas Committee by the voting members of the PGC at a regular meeting. Nominations for Chairman will be made by the Board of Directors and nominations will also be received from the floor. Normally, the Chairman will be elected at the fall meeting following publication of the biennial PGC report and will serve for two years. Vacancies will be filled by election at the next regular PGC meeting, following the same procedure and a Chairman so elected will serve for the remainder of the unexpired term. In the absence of the elected Chairman, the President/General Chairman of the Potential Gas Committee will serve as Chairman of the Board of Directors.

The following ex officio voting members: PGC President/General Chairman, PGC Regional Vice Presidents, Secretary of the PGC, Potential Gas Agency Director, Chairmen of Standing Committees, representatives appointed to the PGC from the natural-gas pipeline and natural-gas distribution industries, representative from the Canadian gas industry, representative from the American Gas Association.

In addition, a maximum of five voting Technical Advisors may be appointed by the Potential Gas Committee President/General Chairman, subject to approval by the Potential Gas Agency Director.

Editorial Committee

The Editorial Committee will review and approve the editorial content and format of PGC reports. They will work closely with the Potential Gas Agency in the publication of all official publications of the Potential Gas Committee.

Membership

Chairman, appointed by the Potential Gas Committee President/General Chairman, and approved by the Board of Directors. Six Jmembers of the Potential Gas Committee, appointed by the Editorial Committee Chairman, with approval of the PGC President/General Chairman. PGC President/General Chairman, ex officio; Potential Gas Agency Director, ex officio.

Committee on Definitions and Procedures

This Committee has the responsibility of reviewing and recommending to the membership of the Potential Gas Committee any proposed changes in the definitions and procedures used in the estimation of potential gas resources. Proposals to be reviewed by this Committee may be submitted by any member of the Potential Gas Committee. The Committee will further review estimates of potential gas resources made by other organizations which come to the attention of the Committee and may, from time to time, as deemed appropriate, prepare publications dealing with the comparison of the work of the Potential Gas Committee with that of other organizations. The Committee on Definitions and Procedures will also serve as liaison with the US Geological Survey Resource Appraisal Group and other such organizations as are involved in the work of estimation of potential gas resources.

Membership

Chairman, appointed by the PGC President/General Chairman and approved by the Board of Directors. Four members of the Potential Gas Committee, appointed by the Chairman of the Committee on Definitions and Procedures, with approval of the PGC President/General Chairman. PGC President/General Chairman, ex officio; PGA Director, ex officio.

Time and Site Committee

This Committee will select an appropriate location and date for each national PGC meeting which will serve best the needs of the Committee. Once the site and date of each meeting have been selected by the Committee, the Potential Gas Agency will be charged with the responsibility of completing the arrangements for the meeting. The Time and Site Committee will also coordinate any regional meetings which are scheduled by Regional Vice Presidents in order that the dates of such meetings shall not be in conflict.

Membership

Chairman, appointed by the PGC President/General Chairman and approved by the Board of Directors. Three members of the Potential Gas Committee, appointed by the Chairman of the Time and Site Committee and approved by the PGC President/General Chairman. Regional Vice Presidents, ex officio; PGC President/General Chairman, ex officio; PGA Director, ex officio.

Communications

Communication Between Committees

The formal channel of communication shall be from the Area Work Committees to the Potential Gas Committee to the Potential Gas Agency to the American Gas Association Gas Supply Committee and vice versa.

Public Communication

Members of the Potential Gas Agency, the Potential Gas Committee and the Area Work Committees are encouraged to publicize and explain their work. These efforts should be limited to explaining the methodology used, comparative methodology and the strengths and limitations of the work. When acting as spokesmen for the Committee, members shall refrain from interpreting study results in terms of national policy needs or required industry incentives. Members who are called upon to make talks and write papers on behalf of the Committee should submit texts to the Potential Gas Agency for comment and policy review.

MEMBERSHIP OF THE POTENTIAL GAS AGENCY AND POTENTIAL GAS COMMITTEE

POTENTIAL GAS AGENCY

Harry C. Kent, Executive Director
Joseph J. Finney, Associate Director
Sharon J. Kirts, Staff Assistant

POTENTIAL GAS COMMITTEE

Richard J. Burgess, President/General Chairman
Jeffery V. Morris, Vice President, Eastern Region
Robert D. Habbit, Vice President, Western Region
David A. Rochester, Secretary

Board of Directors

J. C. Herrington, Chairman

Donald W. Axford
Porter J. Brown
Richard J. Burgess
James K. Curry
A. M. Derrick
Joseph J. Finney
Dan B. Grubb
Robert D. Habbit
E. Floyd Humphries
Robert B. Kalisch
Harry C. Kent
Sharon J. Kirts
William E. Mantek
Jeffery V. Morris
Richard J. Murdy
D. Keith Murray
Charles L. Neumeyer
William H. Owens
David A. Rochester
Jack H. Welsh, Jr.

Editorial Committee

William E. Mantek, Chairman

A. M. Derrick
George C. Grow, Jr.
Gordon Marney
Henry Martch
Charles L. Neumeyer
David A. Rochester

ex officio:
Richard J. Burgess
Harry C. Kent

Committee on Definitions and Procedures

A. M. Derrick
Don Hallinger
J. C. Herrington
Wallace A. Howes

ex officio:
Richard J. Burgess
Harry C. Kent

Time and Site Committee

J. C. Herrington, Chairman

Dan B. Grubb

ex officio:
Richard J. Burgess
Harry C. Kent

AREA WORK COMMITTEES

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Jeffery V. Morris, Vice President
Porter J. Brown, Assistant Vice President

Atlantic

George C. Grow, Jr., Chairman
Richard L. Stollar, Vice Chairman

E. Perry Bendler
William E. Bennett
David G. Bowen
Porter J. Brown
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Wayne S. Leeper
Roy W. Lynch, Jr.
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Carl W. Sherman
Arthur Van Tyne
James M. Wigal

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Eugene Myers
Robert L. Peters
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John M. Richart
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enneth Dwight
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Norris E. Pedigo
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Bruce Woodlan
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D. Keith Murray, Assistant Vice President

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Marshall C. Crouch III, Vice Chairman

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Sidney Anderson
Walter Arbuckle
James A. Barlow
David Fischer
C. Keith Fisher
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John D. Haun
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Moid U. Kidwai
Frank E. Kottlowski
Steve Luthy
Gregory W. Martin
J. Paul Matheny
Richard B. Powers
Ron W. Pritchett
John J. Tonnsen
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William F. Edmondson
Dwayne L. Foley
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Edward A. Hall
Kenneth F. Hersh
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Douglas Waterman
Frank E. Weagant
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David M. Hite
Robert H. McMullin

Coalbed Methane

D. Keith Murray, Chairman

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A. David Decker
James P. Kaiser
Bruce S. Kelso
Ed R. Talone
Fred F. Meissner

Technical Advisors

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William E. Bennett
Charles R. Brammell
Billy D. Brown
Richard J. Burgess
Billy C. Cook
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William F. Edmondson
Robert W. Gallagher
Dan B. Grubb
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Merlin A. Johnson
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Lester E. Ludwick
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B. Warren Beebe
A. M. Derrick
George C. Grow, Jr.
John M. Hanley
E. Floyd Humphries
Richard J. Murdy
Charles L. Neumeyer
E. A. Rassinier

Representatives

Dan B. Grubb - Co-Representative, Pipelines
Jack H. Welsh, Jr. - Co-Representative, Pipelines
William H. Owens - Representative, Gas Distributors
Robert B. Kalisch - Representative, American Gas Association

Observers

Ellis R. Boyd, Jr., Division of Reserves & Natural Gas, DOE/EIA
Philip M. Budzik, Natural Gas Supply Association
John Bulger, Gaz Metropolitain, Inc. (Canada)
Lucio A. D'Andrea, Economic Commission for Europe
Gordon L. Dolton, U. S. Geological Survey
W. Timothy Dowd, Interstate Oil Compact Commission
Daniel A. Dreyfus, Gas Research Institute
E. Bruce Hagen, National Assn. of Regulatory Utility Commissioners
Danny Hill, Interstate Natural Gas Association of America
Tommie C. Hillis, Federal Energy Regulatory Commission
Gordon W. Koelling, Division of Reserves & Natural Gas, DOE/EIA
John E. Latz, Bureau of Land Management
Bernard S. Lee, Institute of Gas Technology
Gary L. Lore, The Minerals Management Service
Barry G. Luft, Western Gas Marketing Ltd. (Canada)
Hans Maciej, Canadian Petroleum Association (Canada)
John B. Maher, Jr., Polaris Petroleum Ltd. (Canada)
Richard D. Miller, U.S. Bureau of Mines
Patrick O'Shea, Gas Research Institute
Jeremy Platt, Electric Power Research Institute
Darrell L. Sala, Institute of Gas Technology
Wayne M. Thompson, Federal Energy Regulatory Commission
Merlin J. Tipton, American Association of State Geologists

ANCELL, Kenneth L. (1): Dowdle, Fairchild & Ancell, Inc., Houston, TX.

ALLEN, C. M. (11)[+] : Oil and Gas Consultant, Homosassa Springs, FL 1981-. Phillips Petrol. Co., employed in various capacities in the Expl. and Prod. Dept. (Bartlesville, OK) 1944-81. Adv. Board to Dept. of Geol., Univ. KS 1973-76. Mem. Am. Assn. Petrol. Geol. (Comm. on Emergency Preparedness 1974-76, Comm. on U.S. Energy Outlook 1970-73), Fed. Power Comm. Nat. Gas Surv. (Gas Supply Task Force 1971-75). Has testified in numerous state conservation agency, state and federal courts and Fed. Power Comm. proceedings (including all major area and national rate proceedings), and hearings before Senate and House Congressional Committees, PGC Hon. Tech. Adv.

**ALLSHOUSE, Edward M. (5): Sr. Reservoir Geol., El Paso Nat. Gas Co., El Paso, TX 1973-. Mem. Am. Assn. Petrol. Geol. (former SW Sect. Delegate) (CPG #3262), Am. Inst. Min., Met. & Petrol. Engrs. (Past Chmn., El Paso Chapter), El Paso Geol. Soc. (Past Pres.), PGC Rocky Mtn. Area Comm.

ANDERSON, Sherman (3): Ch. Geol., Moore McCormack Energy, Inc., Dallas, TX 1981-; Eastern Dist. Expl. Mgr. 1979-81. Jackson Exploration, Dist. Geol. (Dallas, TX) 1979. Lear Petroleum, Area Geol. (Dallas, TX) 1978-79. Universal Resources, Dist. Geol. (Dallas, TX) 1978. Ensearch Exploration, Sr. Staff Geol., Dist. Geol., Geol. (Tyler, TX, Jackson, MS, Dallas, TX) 1964-78. Diamond Shamrock, Jr. Geol., Geol. (Amarillo, TX) 1955-64. Mem. Am. Assn. Petrol. Geol., PGC Gulf Coast Area Comm.

ANDERSON, Sidney (1): State Geologist, North Dakota Geological Survey, Grand Forks, ND. Mem. PGC Rocky Mtn. Area Comm.

ARBUCKLE, Walter (2): Fossil Associates, Inc., Denver, CO. Mem. PGC Rocky Mtn. Area Comm.

AXFORD, Donald W. (9): Pres., D. W. Axford & Assoc. Ltd, Calgary, Canada 1977-. Pres., D B & K Oils Ltd., Calgary 1977-. Pres., Columbia Basin Energy Corp., U.S. 1982-. Petro-Canada, V. Pres. Expl. & Prod. 1976-77. Mobil Oil (Canada & U.S.), V. Pres. Expl. & Dir. 1948-76. Dir.: Harbour Petrol. Co. Ltd., Highridge Expl. Ltd., Lutheran Life Ins. Soc. Canada. Mem. Am. Assn. Petrol. Geol., Assn. Prof. Engrs., Geol. & Geophys. Alberta, Canadian Soc. Petrol. Geol., Geol. Soc. Am., Geol. Assn. Canada, Soc. Econ. Paleon. & Min., PGC Bd. Dir., Hon. Tech. Adv., Observer - Canada.

BALL, Floyd J. (3): Dir. Gas Reserves & Deliverability, Transco Energy Co., Houston, TX 1986-. Southern Nat. Gas Co., Dir. Gas Reserves 1981-85, Mgr. Reserves Engineering 1978-81; Sr. Engr. 1975-78: Engr. (Birmingham, AL) 1968-70 Mem. Houston Nat. Gas Men's Assn., The Inst. Elec. & Electronics Engrs. Inc., Soc. Petrol. Engrs., Prof. Engr. TX, PGC Gulf Coast Area Comm.

BARLOW, James A. Jr. (6): V. Pres., Barlow & Haun, Inc., Casper, WY 1957-. Forest Oil Corp., Geol. 1953-57. Ohio Oil Co., Geol. 1952-53. Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Scient., Geol. Soc. Am., Rocky Mtn. Assn. Geol., WY Geol. Assn., PGC Tech. Adv., Rocky Mtn. Area Comm.

BARRATT, Michael W. (4): Gen. Mgr., PPG Oil & Gas Co., Denver, CO 1985-. Ladd Petroleum Corp., Mgr. MI Basin Div., Jackson, MI 1984-85. Patrick Petroleum Co., Mgr. MI Basin Div. (Jackson, MI) 1980-84. Michigan Oil Co., Mgr. MI Basin Div. (Alma, MI) 1978-80; Staff Geol. 1975-78. MI Gas Util. Develop. Co., Staff Geol. (Hastings, MI) 1972-75. MI Consolidated Gas Co., Staff Geol. (Detroit, MI) 1969-72. Mem. Am. Assn. Petrol. Geol., MI Basin Geol. Soc. (Past Pres., V. Pres. and Treas.), MI Oil and Gas Assn. (Bd. Dir.), PGC Chmn. - North Central Area Comm.

BEEBE, B. W. (11): Ret., Tulsa, OK 1980-. Geol., Geophys. & Energy Consultant (Boulder, CO) 1972-80. Millison & Beebe (Partner) 1969-72. M. M. & B., Inc., V. Pres. & Sec., 1964-72. Ind. Geol. and Geophys. 1959-64. Keating Drlg. Co., V. Pres. and Dir. 1955-58. Manhart, Millison & Beebe (Partner) 1950-55. Anderson-Prichard Oil Corp., Expl. Mgr. 1947-50. Bay Petrol. Corp., Ch. Geol., Expl. Mgr. (organized Expl. Dept.); V. Pres. 1942-47. Lerke & Whortan, Assoc. Cons. 1939-41. British-American

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[+] Number in parenthesis following name indicates number of Potential Gas Committee reports in which member participated.

*Pipelines representative.

**Gas Distributors representative.

Oil Prod. Co., Div. Geol. 1938-39. Shell Petrol. Corp., Geol. and Asst. to V. Pres. Expl., 1935-38. KS Emergency Relief Comm., Geol. 1934. Mem. Am. Assn. Adv. Sci. (Fellow), Geol. Soc. Am. (Fellow), Am. Assn. Petrol. Geol. (Hon. Mem., Mem. 9: Natural Gases of No. Am. [ed.] 1968, Dist. Lecturer 1969-70), OK Geol. Soc. (Hon. Mem.), Rocky Mtn. Assn. Geol. (Hon. Mem.), Am. Arbitration Assn., Am. Gas Assn., Assn. Prof. Geol. Scientists, KS Geol. Soc., Oklahoma City Geol. Soc., Soc. Expl. Geophysicists, Soc. Ind. Prof. Earth Scientists, Soc. Petrol. Engrs., Rocky Mtn. Nat. Gas Men's Assn., PGC Hon. Tech. Adv.

**BENDLER, E. Perry (11): Supv., Geol., Geol. & Land Serv., The East Ohio Gas Co., Cleveland, OH 1955-. Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol. (Cert. #2473), No. OH Geol. Soc., OH Geol. Soc., OH O&G Assn., PGC Tech. Adv., Atlantic Area Comm.

BENNETT, William E. (11): Pres., Gasamex Ltd./W. E. Bennett Inc., Charleston, WV 1984-; Phoenix Hydrocarbon, Ltd., Pres. 1979-82; Monitor Petrol. Corp., V. Pres.-Expl. (NYC, Charleston, WV) 1976-82; Geol./Geophysicist 1974-76. Monitor Resources Corp., NYC Cons. 1976-82. United Fuel Gas Co., Sr. Geophysicist 1969-74; Geophysicist 1962-68; Geol. 1957-61. Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Scientists (Cert. #1642, Past Pres. WV Sec), Soc. Expl. Geophysicists, Ind. O&G Assn. WV, Appalachian Geol. Soc., Fed. Power Comm. Nat. Gas Surv. (Tech. Adv. 1975-76), Am. Gas Assn. (Atl. Action Comm. 1974-75), Cert. Prof. Geol. - Commonwealth of VA #6, PGC Tech. Adv., Atlantic Area Comm.

BOWEN, David G. (5): Cons. Geol., New Orleans, LA 1986-. Ansythe Exploration Co., Oper. Mgr., New Orleans, LA 1981-1985. Eason Oil Co., Dist. Expl. Mgr. 1978-81. Florida Gas Expl. Co., Div. Prod. Geol. 1969-78. Chevron U.S.A., Expl. Geol. 1967-69; Geophys. 1965-67; Dev. Geol. 1961-65; Expl. Geol. (Billings, MT) 1959-61. United Fuel Gas Co., Asst. Geol. (Charleston, WV) 1955-57. Mem. Am. Assn. Petrol. Geol., New Orleans Geol. Soc., PGC Atlantic Area Comm.

BOYD, Ellis R. Jr. (3): Sup. Petrol. Engr.,Office of Oil & Gas, Div. of Reserves & Nat. Gas, DOE/EIA, Chief, Reserves and Prod. Branch Deputy Dir., Office of Oil & Gas Information System, Washington, DC 1977-. Federal Power Comm., held various positions in Area Rate Div. including Deputy Dir., Planning & Develop. Div.; Bureau of Nat. Gas and Chief, Planning & Spec. Proj. Branch. Marathon Oil Co., various production engineering and supervisory posts, Gulf Coast area 1954-66. Mem. Soc. Petrol. Engrs., PGC Observer - EIA.

BRAMMELL, Charles R. (5): Mgr. Devel. Geol., Odeco Oil & Gas Co., New Orleans, LA 1984-. Graham Energy, V. Pres. Development (Metairie, LA) 1981-84; Consulting Devel. Geol. 1980-81. CNG Producing Co., Mgr. Development 1980; Chief Devel. Geol. 1977-80; Devel. Geol. (New Orleans, LA) 1973-77. Gulf Oil Corp., Expl. & Devel. Geol. 1960-73 and 1957-58. Sinclair Oil & Gas, Expl. & Devel. Geol. 1959-60. Hycalog, Mudlogging Engr. 1958-59. Mem. New Orleans Geol. Soc., PGC Tech. Adv., Gulf Coast Area Comm.

BROWN, Billy D. (4): Mgr., Gas Res. Engr. Dept., Lone Star Gas Co., Dallas, TX 1982-; Sr. Staff Petrol. Engr. 1974-82. Eppler, Guerin & Turner, Acct. Exec. 1967-74. Cornell Oil Co., Petrol. Engr. 1966-67. Texas Pacific Oil Co., Staff Petrol. Engr. 1962-66. Texas Pacific Coal & Oil Co., Petrol. Engr. 1953-62. Mem. Am. Assn. Petrol. Geol., Nat. Gas Soc. No. TX, Soc. Petrol. Engrs. of Am. Inst. Min., Met. & Petrol. Engrs., PGC Tech Adv., Mid-Continent Area Comm.

BROWN, Porter J. (6): Consultant, Charleston, WV 1985-. Columbia Gas Trans. Corp., Chief, Geol. Serv., Charleston, WV 1973-85. United Fuel Gas Co., Ch. Geol. 1960-73; Geol. 1957-60; Asst. Geol. 1950-57. Mem. Am. Assn. Petrol. Geol., Geol. Soc. Am., Appalachian Geol. Soc., Geol. Soc. KY, Geol. Soc. OH, Geol. Soc. PA, Assn. Prof. Geol. Scientists (Cert. #2463), Gas Res. Inst. Indus. Tech. Adv. Comm. (Unconventional Nat. Gas), Prof. Geol. VA (#10), Prof. Petrol. Engr. (KY #4927), Prof. O&G Engr. (WV #5118), PGC Bd. Dir., Asst. V. Pres. - Eastern Region, Atlantic Area Comm.

BROWN, Tom (1): Mgr., Tech. Serv., Diamond Shamrock Expl. Co., Dallas, TX. Mem. PGC Mid-Continent Area Comm.

BUDZIK, Philip M. (1): Nat. Gas Sup. Assn., Washington, DC. PGC Obs.

BULGER, John (2): Dir. Energy Res., Gaz Metropolitain, Inc., Montreal, Canada. Mem. PGC Observer - Canada.

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BURGESS, Richard J. (9): Pres., Northern MI Expl. Co., Jackson, MI 1981-; Exec. V. Pres. 1980-81; V. Pres. 1967-80. Consumers Power Co., Exec. Dir. Expl. 1967-80; Expl. Supv. 1963-67. Panhandle Eastern Pipe Line Co., Geol. 1962. Plymouth Oil Co., Geol. 1960-61. Imperial Oil Ltd. (Canada), Geol. 1954-60. Mem. Am. Assn. Petrol. Geol. (CPG #462), Geol. Soc. Am., MI O&G Assn., MI Basin Geol. Soc., Ontario Petrol. Inst., PGC Pres./Gen. Chmn., Exec. Bd., Bd. Dir., Edit. Comm., Time & Site Comm., Comm. Def. & Proc., Coal. Methane, Tech. Adv., North Central Area Comm.

CARAMANICA, Frank P. (1): Mgr., Dev. Geol., Texoma Prod. Co., Houston, TX. Mem. PGC Gulf Coast Area Comm.

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COOK, Billy C. (6): Thomson-Monteith, Dallas, TX 1984-. Holly Energy, Inc., Chief Geol. (New Orleans, LA) 1981-84. The Louisiana Land and Explor. Co., Geol. (New Orleans, LA) 1972-81. Chevron Oil Co., Dev. & Expl. Geol. 1967-72. Mem. Am. Assn. Petrol. Geol., MS Geol. Soc., New Orleans Geol. Soc., Soc. Econ. Paleon. & Min., PGC Tech. Adv., Atlantic Area Comm.

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D'ANDREA, Lucio A. (7): Chief, Gas Sect., Econ. Comm. for Europe, Geneva, Switzerland 1986-DOE/EIA, Div. of Res. & Nat. Gas, Washington, DC. Experience of about 20 years in various aspects and activities of natural gas industry - production, transportation, distribution and alternate gas supplies. Mem. Soc. Petrol. Engrs., Soc. Military Engrs., PGC Observer - ECE.

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FISCHER, David (1): Subsurface Geol., North Dakota State Geol. Survey, Grand Forks, ND 1983-. Supron Energy Corp., Staff Geol., Denver, CO 1981-83. Gulf Oil Corp., Expl. Geol., Casper, WY 1980-81. Mem. Am. Assn. Petrol. Geol., PGC Rky. Mtn. Area Comm. (alt. for S. Anderson).

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GROW, George C. Jr. (11): Consulting Geol., Westfield, NJ 1974-. Transcontinental Gas Pipe Line Corp., Ch. Geol.-Eastern Area (NJ) 1950-73. The Peoples Natural Gas Co., Jr. Geol. to Ch. Geol. (PA) 1939-50. Standard Oil Co. (NJ), Geol. (Venezuela) 1938-39. Mem. Am. Assn. Petrol. Geol. (Cert. #31, Treas. 1974-76, Adv. Council 1976, Fndn. Dev. Coord. 1974-79), Am. Inst. Min., Met. & Petrol. Engr., Am. Inst. Prof. Geol. (Cert. #1774), Geol. Soc. Am. (Fellow), Soc. Indep. Prof. Earth Scientists (Cert. #1079), Pittsburgh Geol. Soc. (Past Pres.), Am. Gas Assn. (Comm. Underground Storage 1951-73, Chmn. 1960-61; Task Group on Gas Storage Statistics, Chmn. 1964-71), PA Oil & Gas Assn., Ind. Oil & Gas Assn. WV, Lamont-Doherty Geol. Observatory, Columbia Univ. (Adv. Council), Fed. Power Comm. Nat. Gas Surv. (Underground Storage Task Force 1972-73; Prospective Expl. & Dev. Task Force 1975-78), PGC Bd. Dir., Hon. Tech. Adv., Edit. Comm., Chmn. - Atlantic Area Comm.

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HABBIT, Robert D. (7): Habbit Enterprises, Inc., El Paso, TX 1983-. El Paso Natural Gas Co., Mgr. Reservoir Engineering (El Paso, TX) 1978-83; Mgr. Reservoir Studies 1978; Cons. Reservoir Geol. 1977-78; Staff Geol. 1966-77. Ind. Geol. (Houston, TX)

1965-66. El Paso Natural Gas Co., Sr. Reservoir Geol. (Houston) 1957-65. Sohio Petroleum Co., Geophysicist/Geol. (Gulf Coast-Rocky Mtns.) 1954-57. Mem. Am. Assn. Petrol. Geol. (CPG #166), Am. Inst. Prof. Geol. (Cert. #2489), Am. Inst. Min., Met. & Petrol. Engr., Soc. Expl. Geophysicists, Rocky Mtn. Assn. Geol., El Paso Geol. Soc., PGC Bd. Dir., V. Pres. - Western Region.

HAGEN, Bruce (5): Commissioner, North Dakota Public Service Commission, Bismarck, ND 1961-; Deputy Motor Vehicle Registrar for ND 1961. Farmer in Benson and Ramsey Counties in ND 1956-. Mr. Hagen has testified many times before Senate and Congressional committees, as well as government boards and commissions, regarding boxcar supply rail rates and related transportation problems, energy rates and problems, national strip-mine legislation and telephone problems. Mem. Federal Communications Comm. (Alaskan Joint Board, Uniform System of Accounts Joint Board) Mid-America Regulatory Comm., ND United Nations Day Chairperson 1986, Natl. Assn. Reg. Util. Comm. (Mem. Exec. Comm., Chmn. Communications Comm.), Regional Energy Adv. Bd. of U.S. Dept. of Energy, Regulatory Council, State Intermodal Transportation Team (Chmn. 1977-80; 1985), Western Governors' Assn. Economic Research Center Task Force. Served on Advisory Council for the State Regulatory Communications Study Project conducted by the Annenberg School of Communications (graduate school of University of PA), PGC Observer - NARUC.

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HALLINGER, Donald E. (10): Reg. Mgr. Expl., Pacific Interstate, Los Angeles, CA 1977-; Sr. Geol. 1966-77. Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Scientists (Cert., Past Sec.-Treas.), Geol. Soc. Amer., Soc. Econ. Paleon. & Min., Soc. Prof. Well Log Analysts, Regis. State of CA, PGC Tech. Adv., Comm. Def. & Proc.

HANLEY, John M. (9): Retired, Omaha, NE 1973-. Northern Nat. Gas Co., V. Pres.-Gas Supply Studies 1965-73; V. Pres.-Long Range Planning 1963-65; V. Pres.-Gas Supply 1950-63; Supt. Prod./Head Dept. 1942-50; Prod. Engr. 1936-42; Gas Field Supt. (KS) 1933-36. Mem. Soc. Petrol. Engrs., Am. Gas Assn. (Nat. Gas Reserves Comm. 1945-56; Chmn. Nat. Gas Prod. Comm. 1956), Natl. Petrol. Council (Comm. on U.S. Energy Outlook 1970-72), Fed. Power Comm. (Nat. Gas Surv., Gas Supply Task Force 1970-73), Adv. Comm. on Energy to Sec. Int. 1970-71, PGC Hon. Tech. Adv.

HANSON, William B. (1): Geol. Assoc., Amoco Prod. Co., Denver, CO 1983-. Chris Craft Oil Co., Chief Geol., Denver, CO 1982-83. Davis Oil Co., Geol., Denver, CO 1981-82. Amoco Prod. Co., Proj. Geol., Denver, CO 1975-81. Oregon State Univ., Teaching Asst., Corvallis, OR 1974-75. U.S. Geol. Surv., Geol., Lakewood, CO 1971; Hydrologic Field Asst., Portland, OR 1968. Mem. Am. Assn. Petrol. Geol., Soc. Econ. Paleon. & Min., Rocky Mtn. Assn. Geol., WY Geol. Assn., PGC Rky. Mtn. Area Comm.

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HAWK, David H. (6): Dir., Energy Management Services, J. R. Simplot Co., Boise, ID 1984-. Horn Resources Corp., Sr. V. Pres. (Boise, ID) 1981-84. Sundance Oil Co., V. Pres. Expl. (Denver, CO) 1980-81. IGC Production Co., V. Pres. & Gen. Mgr., and

Intermountain Gas Co., Mgr. Expl. & Prod. (Boise, ID) 1977-80; Nat. Res. Advisor 1973-76. Tenneco Oil Co., Expl. Geol. (Denver, CO) 1972-73. Atlantic Richfield, Expl. Geol. (Dallas, TX & Lafayette, LA) 1970-72. Lecturer at numerous national energy symposia. Mem. Am. Assn. Petrol. Geol. (Energy Minerals Div.), ID Assn. Prof. Geol., Geol. Soc. Am., Rocky Mtn. Assn. Geol., PGC Rocky Mtn. Area Comm.

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HOWES, Wallace A. (1): V. Pres., H. Zinder and Associates, Houston, TX & Washington, DC 1985-. San Antonio Nat. Gas Pipeline Co., Dir. Reservoir Eval., Amarillo & Houston, TX 1956-82. Panhandle Eastern Pipeline Co., Ch. Reserves Engr., Liberal, KS & Kansas City, MO 1950-56. USNR, Lt. Commander, Pacific Theater 1941-46. Mem. Am. Gas Assn. (Comm. on Proved Gas Reserves 1957-, Mid-Cont. Subcomm. , Chmn. Rocky Mtn. Subcomm. Expl & Prod. Comm, Program Chmn.), Nat. Gas Men of Houston (Director), Am. Mgt. Assn., Am. Petrol. Inst., Reg. Engr. TX (#15549), Soc. Petrol. Engrs. 1949- (Chmn. Panhandle Sect., Chmn. Gas Tech. Comm., V. Chmn. fall meeting Program Comm.), U.S. Off. Tech. Assess. Comm., PGC Comm. Def & Proc.

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Staff Asst. Explor. Mgr., MI, IL & Anadarko Basins 1949-59. Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Sci., MI Basin Geol. Soc. (Director), MI Oil & Gas Assn. (V. Chmn., Oil & Gas Adv. Bd.), PGC Bd. Dir., Tech. Adv., North Central Area Comm.

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KELLER, Stanley J. (5): Dept. of Nat. Resources, IN Geol. Survey, Bloomington, IN 1953-. Mem. Am. Assn. Petrol. Geol., Am. Petrol. Inst., IN-KY Geol. Soc., IN Geol. Soc., PGC North Central Area Comm.

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VAN TYNE, Arthur M. (1): Geol. Consultant, Van Tyne Consulting, Wellsville, NY 1981-. NY State Geol. Survey, Sr. Geol.-in-Charge, State Oil & Gas Office, Wellsville and Alfred, NY 1958-81. Shell Oil Co., Geol., Baton Rouge, LA 1955-57; Geol. Training, Houston, TX 1954-55; Geol., Jackson, MS 1954; Field Geol., Denver, CO 1953-54. Syracuse Univ. Research Inst., Refrac. Seis Crew and Intern, Geol. Div., Syracuse, NY 1951-53. Mem. Am. Assn. Petrol. Geol., Am. Geophys. Union, Am. Petrol. Inst. (subcommittee on oil reserves, NY and PA and Comm. on Statistics of Drilling - 1965-present), Buffalo Assn. of Prof. Geol., Ind. Oil and Gas Assn. of NY (President - 1985-87, Secretary and Director), Ind. Petrol. Assn. of Am., International Oil Scouts Assn., Interstate Oil Compact Comm. (Research Comm.), NY State Geol. Assn., NY State Oil Producers Assn (Director), Northern Appalachian Geol. Soc. (Past Pres.), Ontario Petrol. Inst., PA Oil and Gas Assn., The New York Acad. of Sciences, PGC Atlantic Area Comm.

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WAINWRIGHT, Kenneth E. (4): Consulting Geol., Bakersfield, CA 1985-. ARCO Oil & Gas Co., Sr. Geol. Assoc., Bakersfield, CA 1979-85; Sr. Geol. 1977-79; Geol. 1970-77; Geol. (Roswell, NM) 1967-70; Geol. (Denver, CO) 1962-67. Mem. Am. Assn. Petrol. Geol., San Joaquin Geol. Soc., PGC Chmn. - Pacific Area Comm.

WATERMAN, Douglas R. (8): Asst. to Gen. Mgr., Chevron U.S.A. Inc., San Ramon, CA; Mgr. Devel. Geol.,West. Reg. Prod. Dept., 1984-. Standard Oil Co. of CA, Geol. Cons./Adv., Foreign Oper. Staff (San Francisco, CA). Chevron U.S.A. Inc., Dist. Supt. Sacramento-San Joaquin Dist; Dist. Supt., Coastal Dist., So CA; Dist. Geol., Ventura Dist. & West. Dist., So. CA; Area Geol., Santa Barbara Channel, CA, So. CA; Seismic Crew Rep., LA & Sacramento Basins & Salton Trough, CA, Cook Inlet, AK, So. CA; Dist. Geol., Salinas & So. San Joaquin Basins, So. CA; Geol., Subsurf. Geol., San Joaquin, Salinas & Santa Maria Basins, CA, So. CA; Geol., Oil Field Study & Second Recovery, San Joaquin Basin, CA, So. CA; Geol., Well Site Geol., Central & Southern CA, So. CA. Mem. Am. Assn. Petrol. Geol., No. CA Geol. Soc., CA Reg. Geol. number 695, PGC Pacific Area Comm.

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WELSH, Jack H. Jr. (2): Sr. V. Pres., Gas Supply, Texas Gas Transmission Corp., Houston, TX (also V. Pres. & Dir. of Gas Supply, Dir. Publ. Relations, Contract Rep.), Houston, TX and Owensboro, KY 1957-. Sun Oil, Titleman (Beaumont, TX) 1953-57. Statistical Accountant (Mene Grande, Venezuela) 1947-50. Mem. Am. Gas Assn., Interstate Nat. Gas Assn. Am., Nat. Gas Men of Houston and New Orleans, Nat. Gas Soc. North TX, Mid-Cont. Gas Assn., So. Gas Assn., PGC Bd. Dir. - Co-Rep., Pipelines.

WIGAL, James M. (5): Dist. Expl. Mgr., Adobe Resources Corp., Pittsburgh, PA 1981-. The Peoples Nat. Gas Co., Geol./Geophys./Expl. Mgr. 1975-81. Dept. of Energy/Bureau of Mines, Geol. (Morgantown, WV) 1974-75. Mem. Am. Assn. Petrol. Geol., Soc. Econ. Paleon. & Min., Soc. Econ. Geol., Soc. Prof. Well Log Anal., PGC Atlantic Area Comm.

WOODBURY, H. O. (3): Geol., Denver, CO 1984-. Chevron U.S.A. Inc., Div. Geol. Rocky Mtn. Div., Denver, CO 1981-84 Standard Oil Co. of CA (Indonesia) 1979-81; (New Orleans, LA) 1972-81; (Tripoli, Libya) 1971-72; New Orleans, LA) 1965-71; Chevron Research Corp. (LaHabra, CA) 1964; (New Orleans, LA) 1955-64; (Casper, WY and Denver, CO) 1946-55. Mem. Am. Assn. Petrol. Geol. (Cert.), Rocky Mtn. Assn. Geol., PGC Chmn. - Rocky Mtn. Area Comm.

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ZARESKI, Gordon K. (4): Sr. V. Pres., H. Zinder & Assoc., Washington, DC 1979-. Department of Energy, Office of Oil & Gas Information System, Dir. (Washington, DC) 1977-79. Federal Power Comm., Bureau of Nat. Gas, Ch. of Planning & Development (Washington, DC) 1969-77. Mem. Am. Assn. Petrol. Geol., Geol. Soc. Washington, DC, PGC Tech. Adv.

Late Addition

DeBUSSCHERE, Gerard (1): Sr. Geol., Sun Explor. & Prod. Co., Dallas, Tx 1983-; Geol. 1982-83. ANR Storage Co., Sr. Geol., Detroit, MI 1980-81. MI Consol. Gas Co., Geol., Detroit, MI 1977-79. Mem. Am. Assn. Petrol. Geol., Soc. Petrol. Engrs., Soc. Prof. Well Log Analysts, MI Basin Geol. Soc., Dallas Geol. Soc., PGC North Central Area Comm.

OVERSIZE FOLDOUT(S) FOUND HERE IN THE PRINTED EDITION OF THIS VOLUME ARE FOUND FOLLOWING THE LAST PAGE OF TEXT IN THIS MICROFICHE EDITION.

SEE FOLDOUT NO 1-2

ERRATA

Potential Supply of Natural Gas in the United States (December 31, 1986)

Potential Gas Committee

Pages 3 and 47:

The last two paragraphs in the left-hand column should read:

> In the Gulf Coast Area several changes have been made in resource estimates. Developments in the Eastern Gulf of Mexico, shelf and slope (provinces P-930 and P-931), as well as adjacent onshore regions in the Louisiana-Mississippi-Alabama Salt Basins Province (P-300), related to the Lower Mobile Bay Norphlet play, have resulted in reevaluation of the natural gas potential for this region. Estimates of most likely Probable resources have been increased slightly with a corresponding decrease in some estimates of Possible and Speculative resources.
>
> In the Texas Offshore, shelf and slope provinces (P-940 and P-941) have been completely reevaluated in view of the fields which have been discovered to date and additional data which have become available as a result of the newly instituted area-wide leasing programs. The most likely estimate of Probable resources for P-941 was reduced because only three fields are currently under development. However, the estimate of Possible resources was increased based on the new data. The slope province is still in the early stages of exploration, and large portions of the shelf province have been only sparsely drilled. The study demonstrated a much larger portion of the shelf (P-940) resources should be classified as Possible rather than Probable with the total most likely estimate remaining essentially unchanged.

Page 16:

The caption for Table 2 should read:

> Table 2. Potential Gas Committee *1986* estimates by Area

Estimates for the Atlantic Area, Possible resources, Onshore, should read:

0-15,000'	***7,730***
15-30,000'	***400***

Page 18:

Table 4 should read:

Table 4. Estimated potential supply of natural gas, December 31, 1986
Onshore, 0-15,000'
(Most Likely Values--billion cubic feet)

AREA	PROBABLE	POSSIBLE	SPECULATIVE
Atlantic	21,950	***7,730***	23,370
North Central	187	4,113	10,323
Gulf Coast	10,850	15,660	3,570
Mid-Continent	30,700	39,500	27,900
Rocky Mountain	27,547	29,352	17,762
Pacific	1,345	5,450	6,000
TOTAL LOWER 48 STATES	92,579	***101,805***	88,925
Alaska	6,590	16,400	27,690
TOTAL UNITED STATES	99,169	***118,205***	116,615

Table 5 should read:

Table 5. Estimated potential supply of natural gas, December 31, 1986
Onshore 15,000-30,000'
(Most Likely Values--billion cubic feet)

AREA	PROBABLE	POSSIBLE	SPECULATIVE
Atlantic	*	***400***	11,060
North Central	**	**	*
Gulf Coast	9,500	21,460	13,380
Mid-Continent	16,900	51,300	34,200
Rocky Mountain	9,004	23,931	7,704
Pacific	200	1,150	900
TOTAL LOWER 48 STATES	35,604	***98,241***	67,244
Alaska	**	**	*
TOTAL UNITED STATES	35,604	***98,241***	67,244

*Negligible quantity of resource estimated.
**Production has not been established; no Probable or Possible resource exists.

Page 20:

Table 8 should read as follows:

Table 8. Comparison of estimates of ultimately recoverable volumes of natural gas in the United States (trillion cubic feet)

TOTAL UNITED STATES

Year	Cumulative Production(1)	Proved Reserves(2)	Potential Resources(3)	Ultimately Recoverable Resource
1968	348	287	1,227	1,862
1970	391	291	1,178	1,860
1972	436	266	1,146	1,848
1974	480	237	1,146	1,863
1976	519	216	948	1,683
1978	558	200	1,019	1,777
1980	596	199	913	1,708
1982	633	202	876	1,710
1984	666	197	784	1,647
1986	698*	193**	739	1,630

LOWER 48 STATES

Year	Cumulative Production(1)	Proved Reserves(2)	Potential Resources(3)	Ultimately Recoverable Resource
1966	310	286	690	1,286
1968	348	282	795	1,425
1970	391	260	851	1,502
1972	435	235	780	1,450
1974	479	205	780	1,464
1976	518	184	748	1,450
1978	556	169	830	1,555
1980	594	166	768	1,528
1982	630	167	742	1,539
1984	662	163	647	1,472
1986	694*	160**	620	1,474

* estimate

** 1985 estimate of Energy Information Administration, Department of Energy

(1) Cumulative production figures derived from A.G.A. Committee on Natural Gas Reserves, plus annual production reports from US Department of Energy, Energy Information Administration.

(2) Proved reserves derived from reports of the A.G.A. Committee on Natural Gas Reserves for years through 1979. Proved reserves for years from 1980 on are derived from reports of US Department of Energy, Energy Information Administration.

(3) Potential resources from estimates of Potential Gas Committee.

Page 35:

Table 11. The following values should be corrected:

		POSSIBLE (most likely)	SPECULATIVE (most likely)
P-120, Appalachian basin	15-30,000'		***4,310***
P-130, Piedmont-Blue Ridge province,	15-30,000'		***3,930***
TOTAL, onshore	0-15,000'	***7,730***	
TOTAL, onshore	15-30,000'	***400***	

Page 56:

Table 13. The following value should be corrected:

		SPECULATIVE (maximum)
P-930, Eastern Gulf Shelf	0-200 m	***10,000***

Page 121:

line 2, left-hand column: ("gaseous coal seams" should read *("gaseous coal seams").*

line 34, right-hand column: internatl should read *internal.*

Page 123:

line 30, left-hand column: fruitland should read *Fruitland.*

Page 144:

under listing of Mid-Continent Committee: enneth Dwight should read *Kenneth Dwight*

P-960-961
PACIFIC OFFSHORE
(0-200m)SHELF
(200-1000m)SLOPE
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
CANADA
WESTERN REGION
EASTERN REGION
P-600
P-610
EASTERN COLUMBIA BASIN
OREGON-WASHINGTON COASTAL BASINS OKANOGAN PROVINCE
SWEETGRASS ARCH, CENTRAL MONTANA UPLIFT
Northern Thrust Belt
P-570
P-575
MONTANA FOLDED BELT
P-500
WILLISTON BASIN
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
WISCONSIN
SNAKE RIVER BASIN
P-580
ROCKY
P-515
BIG HORN BASIN
P-510
POWDER RIVER BASIN
Central Thrust Belt
WIND RIVER BASIN
P-520
P-590
WYOMING-UTAH-IDAHO THRUST BELT
GREATER GREEN RIVER BASIN, HANNA-LARAMIE BASINS
P-530
SACRAMENTO BASIN
GREAT BASIN, SIERRA NEVADA, KLAMATH MTNS., SOUTHERN OREGON
P-620
PACIFIC
P-640
P-535
DENVER BASIN, CHADRON ARCH, LAS ANIMAS ARCH
Southern Thrust Belt
P-540
UINTA-PICEANCE BASIN, PARK BASINS, EAGLE BASIN
PARADOX BASIN
P-550
P-650
SAN JOAQUIN BASIN
CALIFORNIA COASTAL BASINS
P-660
P-630
SOUTHEASTERN CALIFORNIA BASINS
MOUNTAIN
P-565
PLATEAU PROVINCE, BLACK MESA BASIN
SAN JUAN BASIN
P-555
P-545
SAN LUIS BASIN, SAN JUAN MTNS., SIERRA GRANDE UPLIFT, LAS VEGAS-RATON BASIN
P-560
SOUTHERN BASIN & RANGE PROVINCE
P-400
CENTRAL KANSAS UPLIFT, SALINA BASIN, NEMAHA ANTICLINE, SEDGWICK BASIN
MID-
P-420
PALO DURO BASIN, AMARILLO-WICHITA UPLIFT, ANADARKO BASIN
P-430
FT. WORTH BASIN, BEND ARCH, STRAWN BASIN
CONTINENT
P-240
WISCONSIN ARCH, SIOUX UPLIFT, IOWA SHELF
Midcontinent Rift
NORTH
P-200
MICHIGAN BASIN
P-260
FOREST CITY BASIN, CHEROKEE BASIN
P-250
LINCOLN ANTICLINE, OZARK UPLIFT
P-220
ILLINOIS BASIN
CENTRAL
P-210
CINCINNATI ARCH
P-410
ARKOMA BASIN
P-230
UPPER MISSISSIPPI EMBAYMENT
P-150
BLACK WARRIOR BASIN
NEW ENGLAND PROVINCE, ADIRONDACK UPLIFT
P-100
P-120
APPALACHIAN BASIN
ATLANTIC
P-910-911
ATLANTIC OFFSHORE
(0-200m)SHELF
(200-1000m)SLOPE
Eastern Thrust Belt
PIEDMONT-BLUE RIDGE PROVINCE
P-130
ATLANTIC COASTAL BASIN
P-110
P-320
EAST TEXAS BASIN
GULF
P-300
LOUISIANA-MISSISSIPPI-ALABAMA SALT BASINS
COAST
SOUTH GEORGIA-PENINSULAR FLORIDA SEDIMENTARY PROVINCE
P-140
P-310
LOUISIANA GULF COAST BASIN
P-330
TEXAS GULF COAST BASIN
P-940-941
TEXAS OFFSHORE
(0-200m)SHELF
(200-1000m)SLOPE
P-935-936
LOUISIANA OFFSHORE
(0-200m)SHELF (200-1000m)SLOPE
P-930-931
EASTERN GULF COAST OFFSHORE
(200-1000m)SLOPE
(0-200m)SHELF
P-915-916
WEST FLORIDA OFFSHORE
(0-200m)SHELF (200-1000m)SLOPE
GULF OF MEXICO
WESTERN REGION
EASTERN REGION
MEXICO

Plate 1

POTENTIAL GAS COMMITTEE

NATURAL GAS MAP OF THE UNITED STATES

December 31, 1986

- ■ AREAS OF GAS PRODUCTION INCLUDING GAS ASSOCIATED WITH OIL
- ☐ AREAS IN WHICH SEDIMENTARY ROCKS ARE EXPOSED AT THE SURFACE OR ARE PRESENT AT DEPTH AND COVERED AT THE SURFACE BY EXTRUSIVE IGNEOUS ROCKS
- ☐ AREAS IN WHICH INTRUSIVE IGNEOUS ROCKS OR METAMORPHIC ROCKS ARE EXPOSED AT THE SURFACE
- LIMITS OF SEDIMENTARY BASINS AS RECOGNIZED BY THE POTENTIAL GAS COMMITTEE, DASHED WHERE INFERRED
- CONTOUR LINE INDICATING THICKNESS OF SEDIMENTS

1986 ESTIMATED POTENTIAL RESOURCES OF NATURAL GAS
(Trillion cubic feet-most likely estimates)

AREA	PROBABLE RESOURCES	POSSIBLE RESOURCES	SPECULATIVE RESOURCES
ATLANTIC	21.95	8.13	49.88
NORTH CENTRAL	0.19	4.11	10.32
GULF COAST	45.58	97.36	33.44
MID-CONTINENT	47.60	90.80	62.10
ROCKY MOUNTAIN	36.55	53.28	25.47
PACIFIC	1.78	15.51	15.73
TOTAL LOWER 48	153.65	269.19	196.94

Western Thrust Belt

The Western Thrust Belt, especially the central portion which is located along the Wyoming-Idaho border, has become a major target for exploration. Significant gas fields have been discovered in southwestern Wyoming and northern Utah. While the eastern boundary of this belt is fairly well defined by the limits of thrust faults, the western boundary is much more nebulous. Some interpretations extend the Western Thrust Belt southeastward from southern Nevada through Arizona, southestern New Mexico, westernmost Texas and into Mexico. At the present time, the only areas within the Thrust Belt in which estimates of potential resources of natural gas have been made are the northern, central and southern portions indicated on the map. Because of lack of positive confirmation of the extension of the Thrust Belt south of Utah and the lack of data on potential source rocks, reservoir rocks and trapping mechanisms, no estimate of any potential resource of natural gas has been made for this area.

- ☐ Exposed Sediments
- ☐ Concealed Sediments

Eastern Thrust Belt

Geophysical data and resulting exploratory activity have led to the interpretation of an Eastern Thrust Belt extending from Canada southward into Georgia and Alabama. In the western portion of this belt, sedimentary rocks are exposed at the surface. In the eastern portion, sedimentary rocks are believed to exist beneath metamorphic rocks. Preliminary estimates of natural gas resources for the Eastern Thrust Belt are included in the estimates reported for the Atlantic Area.

Lower Mobile Bay Norphlet Play

Significant natural gas has been discovered in Lower Mobile Bay and the immediately adjacent federal waters in an eolian facies of the Norphlet Formation. Producing depths exceed 20,000 feet. Fields found to date are estimated to range in size from 200 Bcf to in excess of 1 Tcf. Lateral extent of the play is not completely known, but initial estimates of the resource potential have been included in the estimates for provinces P-300 and P-930.

Mid-Continent Rift

Exploration interest has been focused on the Mid-Continent Rift Zone which traverses the North Central Area from northeastern Kansas and Nebraska to northern Minnesota and Wisconsin. The feature is defined primarily on the basis of geophysical data. It is postulated that considerable thicknesses of sedimentary rocks were deposited along this tectonic trend in elongate fault-block basins which may contain potential reservoir and source rocks. The faulting which is associated with the Rift Zone may have originated in Precambrian time and have continued to affect Paleozoic sedimentation as well.

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